THE PERCY SLADEN TRUST EXPEDITIONS TO THE ABROLHOS ISLANDS (Indian Ocean).

Under the Leadership of Prof. W. J. Dakin, F.L.S., F.Z.S.

Report I.—Introduction, General description of the Coral Islands forming the Houtman Abrolhos Group, the Formation of the Islands. By W. J. Dakin, D.Sc., F.L.S., Professor of Biology, University of West Australia.

(Plates 10–14, and 12 Text-figures.)

[Read 1st February, 1917.]

INTRODUCTION.

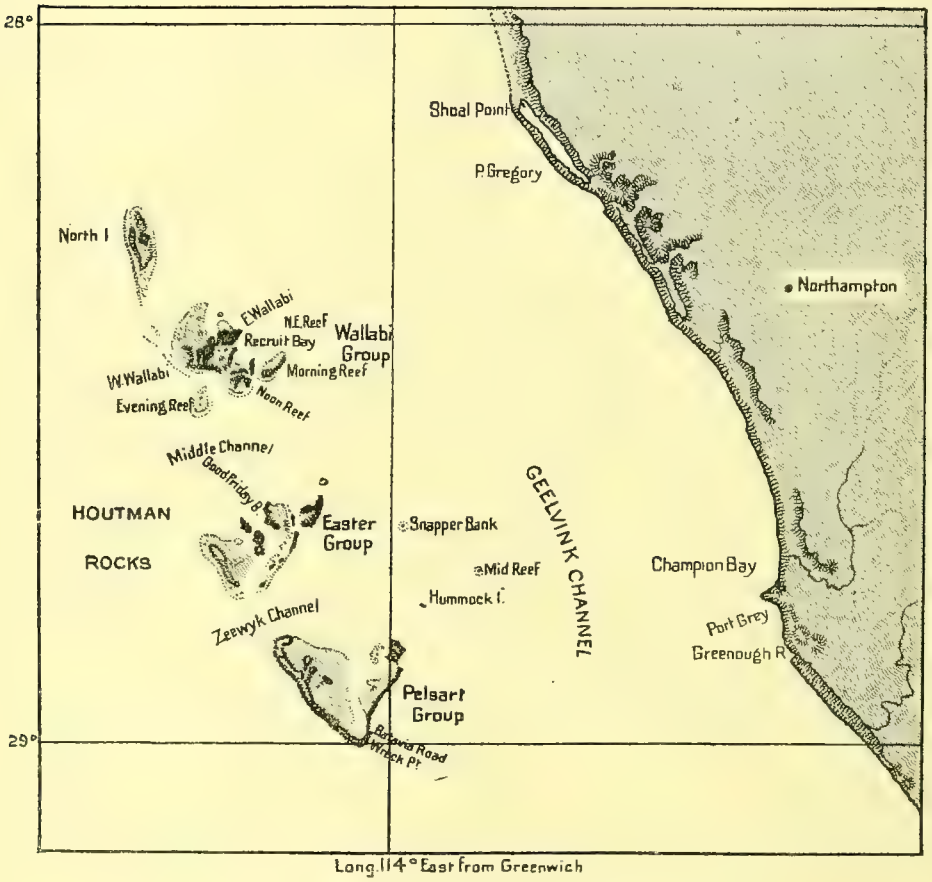
Shortly after my arrival in Western Australia in 1913 my attention was drawn to the interesting position of certain coral islands known as the Houtman's Abrolhos Islands. I determined to visit the group at the earliest possible date, and to this end applied to the Trustees of the Percy Sladen Trust for a grant in aid. An expedition was planned and left the Australian Coast in November 1913 for the islands. On this occasion I was fortunate in having a very able colleague in Mr. W. B. Alexander, M.A., of the West Australian Museum, and the grant of the Percy Sladen Trustees was supplemented by aid from the University of West Australia and the West Australian Museum. Part of our equipment was conveyed direct to the islands from Fremantle, but the personnel with the rest of our apparatus and stores, etc., travelled by train to the port of Geraldton, where the fishing lugger 'Queen,' a boat of 22 tons, awaited us. The 'Queen' is one of a fleet of fishing-boats which makes Geraldton its headquarters, and fishes the waters round the Abrolhos Islands, and as far north as Shark's Bay.

Geraldton is a port of about 3500 inhabitants, situated on the coast of Western Australia in latitude 28° 46′ S. Although only a small town it ranks as the second or third port in Western Australia, and is the centre for a large agricultural and pastoral area, as well as the Murchison goldfield. It marks the most northerly point on the coast which can be reached by train from Perth, and it will be seen on reference to a map that a great length of the coastline of Western Australia remains to the North and can only be visited with difficulty. There are a few ports which are reached by regular steamers from Perth, but between these places the coast might almost still be termed unexplored; this certainly holds good, from the biological point of view, for the entire coast north of Geraldton with the exception of Shark's Bay.

The Abrolhos Expedition of 1913 extended over a period of three weeks, during which time we worked the 'Queen' from islet to islet, and combined shore collecting with biological and geological observations on the islands, and some dredging in the lagoons and between the island

groups. Extensive collections resulted and many observations of interest and importance were made. As a result it was felt highly desirous that a supplementary expedition should be arranged as part of a scheme embodying the investigation of the North-Western Coast. Fortunately the authorities at home came once more to the rescue, and with the aid of a further grant from the Percy Sladen Trustees, together with help from the Royal Society Grant Committee and the British Association, a second expedition was

Text-figure 1.



General Map of the Houtman Abrolhos Islands.

made possible. On this occasion I was assisted by my colleague, Mr. A. Cayzer, B.Sc., Assistant Lecturer in Biology, University of West Australia. The fishing lugger 'Ada' was chartered and we left Geraldton for the Abrolhos in October 1915, four weeks being spent amongst the islands. I was fortunate in having more hydrographic equipment at my disposal on the second expedition, and a rowboat fitted with a motor was of invaluable service in connection with work in the lagoons. I can heartily recommend

this very cheap type of motor craft for use in sheltered waters such as those of the lagoons. It was even possible to dredge with a small instrument 2 feet long and weighing, without sinkers, 12 lbs., in a most satisfactory manner. Much more time was spent in dredging on the second expedition, the small dredge being worked from the rowboat in the lagoons, whilst an Agassiz trawl was used from the lugger in the more open waters. On both expeditions the skippers and crew were Scandinavians and they helped enthusiastically in the work.

On both occasions we took with us camp equipment. The working plan was as follows. The lugger was sailed to a convenient and sheltered anchorage where we intended to work, and usually quite close to an islet (large or very small as the case might be). A camp was then set up on shore, where my colleagues and myself slept, whilst the crew remained on board. Two or three days might be put in at one anchorage in this way, or we might shift lugger and camp every day according to the work carried out. On some occasions the shore collecting, surveying, and work in the lagoons with the dinghy, occupied all our efforts, so that the lugger was left undisturbed for several days. On other occasions when the weather was suitable for dredging in the open sea, we would start early in the morning and leave our camp on shore, to return in the afternoon with the spoil, which needed sorting, labelling, and preserving.

One of the great difficulties in connection with work at the Abrolhos Islands is to find the right kind of weather. For the greater part of the year the winds and sea are too unruly for continued work in these waters, except from a large vessel, and a large vessel could not be used amidst the coral islets. It appears that the best times are *between* the two well-marked seasons, Summer and Winter (dry and wet seasons), *i.e.* the months of October and November on the one hand and April and May on the other. Both of our expeditions were carried out between winter and summer, but we were not nearly so fortunate on the second occasion, although longer at the islands. On one occasion we hung with two anchors out whilst a gale blew for twenty-four hours ; a nasty coral-reef, just submerged, was situated only about twenty feet behind our stern. No accidents happened, but our work was delayed for several days owing to the bad weather. On another occasion, however, the ocean swell was so reduced to leeward of one of the islands that we were able to follow the outer reef and examine it from the motor dinghy.

Reversing thermometers were used on the second expedition in conjunction with the Ekmann water-bottle, but we were too short of workers to initiate a scheme for the complete oceanographical investigation of this region and were forced to be as economical as possible. Our plankton hauls were made chiefly with the object of comparing the plankton of the lagoons with that of the ocean outside, and for this purpose we usually aimed at taking hauls in

both places on the same day, and about the same time. The catches have not yet been examined in detail, but it was fairly obvious, each time, that the plankton of the lagoons contained large quantities of dead organisms and much debris. On the second expedition blasting gelignite was tried as an experiment for the capture of fish. A detonator was pushed into a stick of gelignite, and, after lighting the fuse, the whole thing was thrown overboard. It only worked satisfactorily over the reefs in moderately shallow water, but we could often throw it amidst shoals of coral-haunting fish in these regions. The burning fuse appeared to attract the fish nearer to the explosive rather than frighten them away. After the explosion, numerous fish would appear on the surface. They were not usually dead, but swimming just as if the gas-bladder were distended. Some species did not rise at all, and it would appear that the ascent of the fish immediately after the explosion is not due to death, but to physiological conditions following the shock.

Another experiment was the use of chloride of lime as a poison in rock-pools. This was suggested to me by Professor Starr Jordan and worked very well, but owing to the tides being rather poor and the wind high on many days when we could have utilized this, it was only tested on a few occasions.

The Houtman's Abrolhos lie about 40 miles away from the coast of Western Australia, on the very edge of the continental shelf in latitude 28° 40′ S. (see map, text-fig. 1). The depth of water over the shelf between the Abrolhos and the mainland is very uniform and averages about 25 fathoms, whilst the same depth occurs between the different groups of islets. A few miles west of them the sounding-line gives depths of hundreds of fathoms.

Unfortunately, the Abrolhos Islands are poorly charted and small maps on a reasonable scale deal only with two of them, together with a small area of lagoon in each case which was probably considered to be well sheltered and providing good anchorage. There are no lights of any kind on the islets, and in consequence the fishermen, who have spent years about this area, will not approach close when the sun has set. As a matter of fact, navigation in the lagoons and about the small islets is only safe when the sun is high, and a hand stationed in the rigging can spot the submerged coral-reefs which occur here and there. Coastal steamers give the Abrolhos a wide berth, but more than one ship has finished her life on these barren reefs. In fact, the history of the islands almost commences with a wreck (1629) and the coral reef of the Pelsart Island is to-day dotted with the scattered remains of a steamer, the 'Windsor,' which became a total wreck a few years ago.

Islands in such a position as the Abrolhos—in close proximity to a continent—are full of interest to the biologist, and this is especially the case when they are coral islands. It is not surprising then to find that they

have already been visited by one or two collectors. They were discovered by the Dutch navigator Houtman in the year 1619, but the name Abrolhos is a contraction of a Portuguese phrase meaning "keep your eyes open." They are now more frequently called the Abrolhos Islands. The West coast of Australia was known before this date, and Saville Kent is quite incorrect in stating that it was Pelsart's discovery of the Abrolhos (1629) that led to the "earliest recorded discovery of the great island-continent of Australia."

The wreck of Pelsart's ship (one of the Dutch East Indian Co.'s vessels) in 1629, led to one of the most romantic episodes in the early history of West Australian exploration.

Pelsart in command of the 'Batavia' left Texel on October 28th, 1628, for the East Indies in company with several other ships, all of which were equipped and commissioned by the Directors of the Dutch East India Company. The ships became separated and the 'Batavia,' continuing her course alone, got among the coral reefs of the Abrolhos Islands and struck before sunrise on June 4th, 1629. Trouble followed thick and fast, and the tribulation of the passengers was accentuated by the drunkenness and disorderly conduct of the soldiers and sailors. The ship's company were, however, eventually landed on two of the small islands of the lagoon in the Pelsart Atoll, and much of the provisions and treasure was also salved. Unfortunately, there was a great lack of water, and as we have already seen, little or none is to be obtained on these islands. This trouble accentuated the spirit of unrest which had broken out, and Pelsart finally decided to set out and seek for water. A section of his crew appeared to be very ripe for mutiny.

For a few days the islands were investigated for water with little success, and then Pelsart set off to the mainland. The mainland, however, seemed to offer no better prospects, and for some time the men were unable to land owing to the surf. Drifting northwards some of the crew eventually made a landing by swimming ashore, but an inhospitable country dispelled all hopes, and ultimately Pelsart decided to make for Batavia in order to seek assistance and report to the Governor the misfortunes which had befallen them. He reached that place safely on July 5th, after a journey of upwards of 1700 miles in an open boat.

Tragic events had in the meantime taken place at the Abrolhos Islands. The Supercargo of Pelsart's ship, a thorough villain, named Cornelis, resolved to take up the life of a pirate on the high seas. To this end, he and his accomplices determined to murder in cold blood all the ship's company (220 souls) with the exception of about 38, and then capture the rescue vessel which Pelsart was expected to bring back with him. By this time the passengers, soldiers, and crew were occupying three of the lagoon islands, some of them having moved to the third in search of water. Cornelis and his company were on the largest island. The murders were carried out on

two of the islands, only a few boys and some women being spared. A few men escaped, however, from this hell and reached the third island with the news, whereupon the party (now forty-five in all) led by a man named Weybehays resolved to defend themselves. Cornelis, who had assumed the title of Captain-General, sent two expeditions against them, but these being defeated he determined to gain his ends by more subtle means. Unfortunately for himself, he was hoist with his own petard, taken prisoner, and some of his men were killed. The rest of the mutineers remained on their islands awaiting the arrival of Pelsart, who had been given assistance and a ship at Batavia. He reached the Abrolhos on September 13, eagerly awaited by the two opposing parties, but four of the third island defenders managed to reach him first and acquainted him with the sad state of affairs. When the mutineers arrived to capture the ship, Pelsart and his men were ready for them. The boarding party was captured, and the rest of the ruffians on their island experienced a like fate. After an investigation of the tragedy, Cornelis and his associates were tortured and put to death—they had murdered over 120 innocent souls,—two other prisoners were marooned on the coast, the survivors of the wreck and mutiny eventually reaching Batavia in safety.

The disaster to Pelsart's ship was not the only one experienced by the Dutch at the Abrolhos—for which reefs their ships seemed to have an unfortunate liking. The 'Luytddorf' is supposed to have been lost here in 1711, whilst in 1727 the 'Zeewyk' was wrecked on the western reef of the Pelsart Atoll.

Pelsart described some of the forms of life met with on the islands and in so doing gave a most interesting account of the wallaby (*Macropus eugenii*, Desm.) which still abounds on two of the islands. This was one of the first written descriptions of a member of the kangaroo family to be given to the world. The diagnosis runs as follows:—"Besides we found in these islands large numbers of a species of cats which are very strange creatures. They are about the size of a hare, the head resembling the head of a civet cat, the fore paws are very short, about the length of a finger, on which the animal has five small nails or fingers resembling those of a monkey's fore paw. The two hind legs on the contrary are upwards of half an ell in length, and it walks on these only on the flat of the heavy part of the leg so that it does not run very fast. Its tail is very long like that of a long-tailed monkey. If it eat it sits on its hind legs and touches its food with its fore paws just like a squirrel or monkey.

"Their manner of generation or procreation is exceedingly strange and highly worth observing. Below the belly the female carries a pouch into which you may put your hand. Inside this pouch are her nipples; we have found that the young ones grow up in this pouch with the nipples in their mouths. We have seen some young ones lying there which were only the

size of a bean, though at the same time perfectly proportioned, so that it seems certain that they grow there out of the nipples of the mammæ from which they draw their food until they are grown up and ready to walk. Still, they keep creeping into the pouch even when they have become very large and the dam runs off with them when they are hunted."

It is worthy of note that the Abrolhos Islands were charted by H.M.S. 'Beagle' under Wickham and Stokes a few years after Darwin's famous voyage in that ship. The vessel was some time at the islands and observations were made on the tides and specimens of the fauna were collected. Most of the names of the islets and passages were given at this time.

Darwin himself refers to the Abrolhos Islands in his famous work on Coral Reefs. He had, however, very little information concerning them, beyond that reported by the surveying ships.

The only serious biological investigations of the Abrolhos prior to our visits were made by naturalists who were attracted by the bird-life. One marine biologist, however, had visited the islands, namely Saville Kent. Whilst making a survey for the Government of Western Australia in 1894, this keen naturalist paid a flying visit to the Abrolhos. He was evidently impressed by them, for in the preface to his work 'The Naturalist in Australia,' he writes (referring to the development of the scientific potentialities of the country) :—"As an indication of the leading position Western Australia is eligible to occupy with relation to one important biological subject, reference may be made to that chapter which deals with the Houtman's Abrolhos. As there demonstrated, very exceptional facilities prevail at that place for the conduct of reef-boring operations and for the prosecution of all methods of investigation relating to coral and coral-life."

A considerable number of terrestrial vertebrates, particularly lizards, were obtained by Gilbert, who visited the islands on behalf of Gould the ornithologist. These specimens have been described in the British Museum Catalogues on the Lizards, Snakes, and Batrachia respectively. After Gilbert's collecting excursion, the next naturalist to visit the Abrolhos was A. J. Campbell, F.L.S. A paper on the zoology of these islands by this worker appeared in the Reports of the Australian Association for the Advancement of Science, Melbourne, 1890. Campbell visited this group in December, 1889. Beyond a few remarks about the Mammals and Reptiles he deals only with the bird-life. Campbell states that the Abrolhos form the greatest "rookery for sea-birds in Australia, and by reason of their geographical position in the sub-tropics, perhaps afford suitable breeding grounds for a greater number of species than any other distinct or limited spot in the world."

The next paper to appear dealing with the Abrolhos was a short article by Helms, who visited the islands in 1898. This author names several plants, speaks in a general way of the corals and fishes, and devotes most attention

again to the birds. Another paper on the bird-life was written by Chas. G. Gibson and published in the 'Emu,' 1908–1909.

It will be seen that whilst the mammals, birds, reptiles, and amphibia have been referred to by three or four visitors to the Abrolhos, nothing in any detail has been published on the marine fauna beyond the work of Saville Kent.

Kent considered that the marine fauna of the Abrolhos was essentially a blend of tropical and temperate species. The tropical species were *not* to be found on the adjacent coast. Rich coral growths were to be seen everywhere (the islands were stated to be almost entirely composed of coral), but the living species were *not* the extra-tropical forms to be seen on the coast in this latitude, but were tropical types.

The Percy Sladen Trust Expeditions to the Abrolhos Islands in the years 1913 and 1915 have been conducted, in the first place, for an investigation into the structure and formation of these coral islets, and in the second place for the purpose of collecting information regarding the fauna and marine flora of this region of the Indian Ocean and West Australian coast. In connection with the latter aim we were particularly interested in the statements made by certain authors (Saville Kent, and Michaelsen of the German Expedition to South-West Australia) that the marine fauna of the Abrolhos was entirely different from that of the coast in the same latitude and only 40 to 50 miles away. We have collected some data with regard to the Hydrography of these regions, but it is extraordinary how little is known even of sea temperatures on the Australian coast, while numerous problems await investigation in connection with the tidal phenomena. It is a pity that the means of communication along the West Australian coast should be difficult and costly, but probably in the future, when this large State has its present vast spaces occupied by energetic emigrants, these difficulties will disappear. The time may even come when the scientific investigation of these coastal waters, with their valuable products of pearl-shell and fish, will be recognised as of just a little importance.

The present paper is concerned with a general description of the Abrolhos Islands and includes an account of their structure and formation. Other papers will follow dealing with the collections obtained on the two expeditions. One paper on a new species of Enteropneusta has already been completed. A short account of the Vertebrates, by Mr. W. B. Alexander, M.A., is also ready. The Sponges are now in the hands of Professor Dendy, and Professor W. A. Herdman has the Ascidians. The Holothurians are being worked up by Dr. J. Pearson of the Colombo Museum, the other Echinoderms by H. L. Clarke. The remaining groups have not yet been distributed owing to the dislocation of work consequent on the war.

The study of the marine fauna of the Abrolhos Region and the North-west coast of Australia forms an interesting sequence to biological work

at Ceylon, and in particular to that of Stanley Gardiner at the Laccadive and Maldive Islands. We have found the reports of Stanley Gardiner's expedition, both on the fauna and the formation of the islands, of very great service.

GENERAL DESCRIPTION OF THE ISLANDS.

The islet group of the Abrolhos extends between 28° 15′ and 29° S. lat. and consists of a large number of islands, the smallest of which are only a few square yards in area and generally uncharted. There is urgent need of a survey, for the maps of the islands leave much to be desired and we often had evidence of the inefficiency of the charts.

The archipelago (for such it might be termed) is about 50 miles in length, and the islands occur in four groups. The most northerly group consists, however, of a single island, North Island, whilst the others (the Wallaby, Easter, and Pelsart Groups) comprise a number of islets which according to our views are closely related to one another. These four collections of islands are separated by channels whose depths are approximately the same as those between the entire Abrolhos Group and the mainland.

It may be noted as a characteristic feature, that all the islets occur on a line running roughly N.N.W.–S.S.E. Furthermore, if an island is much longer than it is broad (and this is frequently the case), the long axis usually runs almost north and south. The submerged reefs are often found to be running in the same direction.

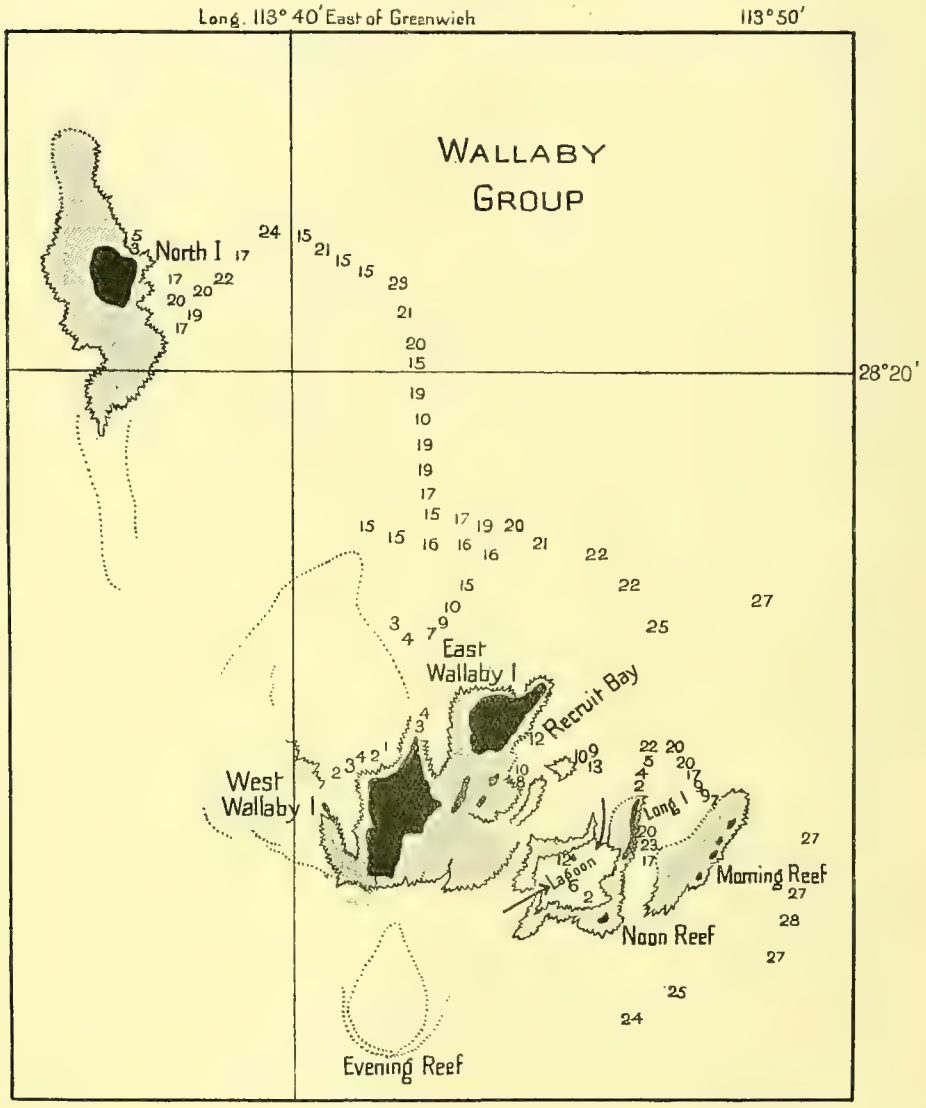
It is usual to leave Geraldton about midnight or early in the morning, so that the islands will not be reached before the sun is well up. It is difficult to observe submerged reefs if the sun's rays are striking the water very obliquely. As a matter of fact, on each occasion that I have visited the islands the night start was quite unnecessary, for unfavourable winds and rough sea prevented us sighting the islands until late in the following afternoon.

Owing to the low elevation of the islands (usually about 8 feet above sea-level), with the exception of some to be mentioned presently, they are not seen until one is quite close. The picture presented is somewhat uninteresting, for the vegetation covering them is very scanty and consists of low bushes. No palm trees occur whatever, the largest plants being mangroves, but these are by no means common and occur on the lagoon flats, so that they are rarely visible from the sea. The gorgeous pictures made by the living coral below the glass-like surface of the water of the lagoons more than makes up for the uninteresting appearance of the surface of the islands. Coral is everywhere in evidence and appears to be growing luxuriously, although the Abrolhos are situated on the extreme southern limit of coral-reef formation.

The islands would be quite uninhabited were it not for a few guano workers who come over for the summer months only, and frequent some

small island or part of a larger one. The fishing luggers are, however, very frequent visitors. These boats are chiefly manned by Italians or Scandinavians and sail from Fremantle or Geraldton. They may fish in the deeper waters round the islands, or send one or two small boats amongst the reefs, whilst

Text-figure 2.



keeping the lugger off during the day. At night, the numerous sheltered regions between the islets are available, and in case of storms a ready harbour is at hand, although, as previously pointed out, it is useless trying to enter the lagoons after sunset.

North Island (see map, text-fig. 2) is the most northerly of the Abrolhos Group. It is situated about nine miles north of the Wallaby (or Wallabi) Isles, and is about one square mile in area. The Wallaby Group proper (see map, text-fig. 2) consists of two large islands, the East and West Wallaby Islands, and a number of small ones which are either unnamed or bear local names given by the fishermen. The West Wallaby Isle is the largest of the Abrolhos Group.

About 14 miles south of the Wallaby Group is situated the Easter Group (see map, text-fig. 1, p. 128). The largest of this collection of islands is Rat Island, which, however, is much smaller than either the East or the West Wallaby Islands.

The Zeewyk Channel (about seven miles across) separates the most southerly islands of the Easter Group and the northern reefs of the Pelsart Group. The largest island of the latter group is Pelsart Island itself (called Long Island by the fishermen), an islet of considerable length extending to the extreme south of the Abrolhos archipelago. Although far exceeding all the other islands in length, being roughly eight miles long, Pelsart Island is in most places only a few hundred feet across, and much of this consists of heaped coral fragments. The Pelsart Group takes much more closely than any of the other groups the form of an atoll, a somewhat triangular atoll, with the apex directed towards the south. Pelsart Island forms part of one side of this triangle. A distinct resemblance is to be traced in the Easter Group to the atoll, but this question will be considered in detail when describing the structure of the different islands.

Saville Kent stated that all the islands of the Houtman's Abrolhos were coral formations with the exception of certain of the Wallaby Group. In this region plutonic rocks were said to occur corresponding to those of the mainland and having an elevation of some 30 or 40 feet. It is difficult to understand to what particular rocks Kent referred, but in any case his remarks are incorrect. The Wallaby Islands were carefully examined and, although they are much larger than the other islets and attain the greatest elevation, there is no trace of any rock other than recent limestone. All the Abrolhos islets are coral formations.

The nearest rock of Kent's plutonic type on the mainland is granite. This has been met with in Geraldton at a depth of 420 feet and it also occurs down the coast. It may be pointed out here that Michaelsen and Hartmeyer in their introductory section to the 'Fauna Südwest-Australiens' speak of the coastal limestone near Fremantle as being uplifted coral-reef. This is also quite incorrect, and it is curious that these German workers failed to notice it. The limestone of the Fremantle coast has been formed by the action of water on vast accumulations of drift sand containing much calcium carbonate. The uplifted coral limestone of the Abrolhos is quite different from this æolian limestone of the more southern coast.

The Abrolhos Islands are favourite nesting places of sea-birds, the chief breeding season being about the months of October and November. During these months enormous numbers of Noddy Terns, Sooty Terns, and Lesser Noddies frequent certain islets and the bushes are covered with their nests. They rise in hundreds as one passes across the islets, although many stop in their nests and refuse to budge unless pushed off. Wherever the coral surface is covered with deposits of sand, etc. the excavations of Mutton-birds abound. One falls through into them at every other step. As might well be imagined, vast accumulations of guano have been formed on the Abrolhos and this was removed on a large scale in the early nineties. Wooden jetties were built and long trackways put down on the Wallaby Islands. Moderately sized vessels called for the fertiliser, which was shipped out of the State. Up to 1898 the records show that 55,000 tons of guano had been excavated and exported. The work is still carried on during the summer months by Mr. Fallowfield of Geraldton, who has the concession from the Government for this purpose, but the amount now shifted is small indeed compared with that of earlier days and it is not allowed to be exported out of the State. The guano deposits have covered the coral surfaces of the islands with a layer a foot or more in thickness. The first step in the process of collecting consists in the removal of all plant-growths from the area being worked. Large loose coral blocks are then picked out of it and stacked, and the rest is shovelled away and screened so that all the small stones are removed. The residue is trucked to the jetty and bagged for shipment to the coast. When the guano deposits are removed in this way, the material is stripped so that the limestone surface of the island is exposed. This is often quite flat and smooth, for the action of the rain, the guano deposits, and the coral has resulted in a compact and rather hard surface limestone. The appearance of such an island afterwards is often curious. The surface is brushed clean of all sand and deposit, whilst walls appear to have been constructed in all directions—they represent the stacked coral blocks picked out of the guano.

The invasion of the islands by guano workers has had an appreciable effect upon the land flora, which consists almost entirely of xerophytic and halophytic shrubs, and many of the plants have been introduced from the mainland. So far as the fauna is concerned the guano workers do not seem to have affected it very much, if at all, except that rats became a plague on Rat Island and cats were introduced to keep down the pest. The rats no longer exist, but a few cats occur in a wild state and probably have a very happy time during the nesting season of the terns.

In concluding this brief general description, it may be pointed out that any expedition visiting the Abrolhos Islands has not only to carry full supplies of provisions, but also fresh water. All the water used by the guano workers has to be carried in tanks from Geraldton and is then laboriously bailed out with kerosene tins and stored in small tanks. In the rainy

season (winter months July–September) there may be enough rain water, but rain which has fallen heavily whilst I have been on the islands has speedily disappeared. One or two wells occur on the larger islands—East and West Wallaby Isles, Rat Island and Pelsart Island, but the water is poor and brackish and often contains too much decaying organic matter to be pleasant.

Meteorological and Hydrographical Conditions.

Records of sea temperatures are very badly wanted on the coast of Western Australia and up to date but little is known. It would seem strange that the Meteorological Department, although so desirous of forecasting weather, has not arranged long ago to take sea temperatures at their coastal stations, especially where these are only a few yards from the sea. What data I have included here has been obtained from a few records made on our expedition and from the work of Mr. J. J. East of Perth. This gentleman collected the sea temperatures recorded by the engine-room staffs on mail and coastal steamers in Australian waters. The temperatures apply to the sea water as pumped into the condensers. Unfortunately this source of our knowledge only covers a period of a few months and goes but little way to fill up a big gap. The results so far are quite interesting.

From the appended table it will be seen that the coast of Western Australia is washed by water the temperature of which ranges from about 15·6° C.–19·4° C., on the south, to 23·3° C.–30·5° on the north-west. The seasonal change at most places is not very great, and the highest sea temperatures are recorded in February and March, the lowest in August and September.

Sea Temperatures (°C.) *

observed in the offing along the West Coast of Australia (chiefly based on the engine-room log of S.S. 'Paroo' during the years 1908–12, voyaging between Fremantle and Singapore, and various coasting steamers, 1912).

	Jan.	*Feb.*	*Mar.*	*Apl.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Derby	..	..	30·0	28·9	27·8	25·9	25·6	25·9	25·6	..	..	30·0
Broome	30·7	30·0	30·0	29·8	27·7	24·7	24·8	24·4	23·3	24·4	28·3	29·4
Hedland.....	29·4	30·0	29·7	27·8	26·7	24·6	22·5	22·7	22·7	25·3	27·2	28·6
Cossack	28·3	29·6	27·8	28·9	27·2	22·5	22·7	21·4	22·7	24·6	26·1	27·2
Onslow	26·8	28·4	28·2	28·6	26·7	22·4	22·9	21·8	23·3	24·4	23·8	27·8
Carnarvon	24·4	25·6	25·9	25·2	24·9	22·5	22·2	20·8	20·6	21·7	21·7	23·3
Geraldton	22·26	23·6	23·7	23·3	21·8	21·4	20·4	19·7	19·5	19·5	20·4	22·7
Fremantle	22·2	22·7	23·3	22·5	20·3	20·8	18·9	17·1	17·8	19·5	20·0	21·9
(10–30 miles N. of port)												
Albany	..	..	..	..	..	19·0	17·8	16·0	..	..	..	..

Note.—Except in the case of Fremantle, the figures are the mean of the observations taken during the watch (10–40 miles run) after leaving, or when approaching, the port named.—Our own temperature observations taken with certificated thermometers indicate that the winter sea temperature at Geraldton is lower than that given in the above table, and the above figures must be taken therefore as only approximate. [W. J. D.]

* I am indebted to Mr. J. J. East of Perth for the compilation of this table.

At Geraldton, the nearest port to the Abrolhos and in the same latitude as the islands, the sea temperature ranges from about 16·7° C. in winter to 23·5° C. in the summer.

[For purposes of comparison the air temperatures taken in the shade at Geraldton during the three years 1913, 1914, and 1915 are appended. I am indebted to the Commonwealth Meteorological Bureau for this information.]

Shade Temperatures at Geraldton in °F.

	Year.	*Jan.*	*Feb.*	*Mar.*	*Apl.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Mean max.	1913.	83·9	85·6	83·2	78·7	78·9	72·6	68·7	67·9	72·9	72·5	76·4	77·5
Highest ..		99·3	106·5	107·2	94·6	90·0	82·0	80·0	74·2	95·0	86·1	104·0	103·3
Mean min.		64·5	66·8	65·1	61·0	55·5	55·6	48·6	51·7	51·0	55·5	58·6	62·9
Lowest ..		56·0	54·3	54·5	51·4	47 0	47·0	37·3	43·0	39·0	46·3	47·0	52·8
Mean max.	1914.	85·0	83·3	82·6	75·1	72·6	71·0	67·6	73·2	76·7	77·0	77·1	79·6
Highest ..		109·8	108·3	105·8	84·0	89·8	83·8	74·2	84·0	95·0	97·8	95·0	101·8
Mean min.		65·6	64·3	62·6	56·3	52·2	51·5	50 0	52·0	53·8	60·6	62·5	65·0
Lowest ..		57·5	54·5	47·0	44·0	40·8	43·0	39·0	43·0	42·0	49·0	53·0	55·4
Mean max.	1915.	86·3	84·4	84·0	82·7	76·0	71·4	68·5	69·4	67·8	72 9	81·9	86·6
Highest ..		100·0	106·8	99·0	97·2	84·8	81·8	74·6	78·3	69·8	96·0	104·6	113·0
Mean min.		69·3	69·0	64·1	64·2	58·5	58·3	54·5	54·4	53·5	56·3	61·0	66·0
Lowest ..		59·0	60·8	54·2	53·0	50·8	53·0	41·6	42·0	46·2	46·0	51·0	54·6

If sea temperatures are taken a few miles away from the coast in the region between Geraldton and Shark's Bay, it will be found that these offshore waters are somewhat warmer than those close to shore in the same latitude.

Now this is an important point, for statements have been made to the effect that the marine fauna of the Abrolhos Islands contains so much of a tropical element that one must travel up to the Tropic of Capricorn before reaching a similar fauna on the coast. Whether this be correct or not*, the fact remains that the Abrolhos are coral islets, and no coral reefs are met with on the coast for many miles north of this latitude. The statements about the tropical character of the Abrolhos fauna were first put forward by Saville Kent, after his very short stay at the islands in 1894. He suggested also as an explanation that an ocean current existed which set in from the equatorial waters of the Indian Ocean and brought down floating larvæ without impinging on the adjacent coast. In support of this, Kent stated that temperatures as low as 56° F. (13·3° C.) were recorded at Geraldton when at the same time the temperatures at the Abrolhos were 14° *F. higher* (21·1° C.). This is a very considerable difference—14° F. between two places 40 miles apart with oceanic conditions prevailing—and it is a great pity that Kent did not give more details concerning his figures.

* According to Mr. Alexander, who has just completed an account of the Fishes from the Abrolhos, the greater number of species are distinctly Southern types (extratropical forms).

On our first expedition to the Abrolhos, leaving Geraldton on November 9th, 1913, the temperature of the sea at Geraldton was 16·7° C. when we started. On our arrival at the islands we found the temperature to be 20° C. Arrangements had been made for the Harbour Master to take some temperatures at Geraldton whilst we were at the islands. The following is a comparison of the figures, the temperatures being taken at the same hour and early in the morning at the two places.

	Geraldton.	Abrolhos Isles.
Nov. 9th, 1913 ...	16·7° C. ...	20° C.
„ 10th, „ ...	16·7° C. ...	20° C.
„ 12th, „ ...	17·8° C. ...	19·75° C.
„ 13th, „ ...	19·4° C. ...	20° C.
„ 15th, „ ...	19·4° C. ...	21° C.

The temperatures at Geraldton were certainly lower than those at the Abrolhos Isles, but a remarkable increase happened to take place within a week at the former place whilst the sea temperatures at the islands remained constant. This was undoubtedly due to a very local heat-wave which visited the mainland causing the temperature to rise to 104° F. in the shade! It would quite easily affect the waters of the Geraldton bay. I am afraid this

Text-figure 3.

illustrates the futility of drawing conclusions from isolated records. At the same time the early temperatures record a difference of about 3° C. between the waters bathing the Abrolhos and those of Geraldton. This is not such a great difference as that noted by Kent, and I am inclined to regard the low temperature of 13·3° C. recorded by him at Geraldton in July 1894 as also abnormal (granting the possibility of error in making the record).

Further information is, however, to be obtained from the engine-room observations already referred to. If isotherms are plotted from the readings of June 1911, it will be seen that a definite tongue of warmer water extends down the coast of West Australia, the tip reaching to about the Abrolhos Islands (text-fig. 3). During this time, a southern movement of equatorial water was taking place, and it was separated from the coast by a distinct zone of cold water which was still more obvious during the following month and extended from the Leeuwin northwards.

The evidence so far collected goes to show, then, that there is a general tendency for the temperature of the sea at the Abrolhos to be slightly higher than that at the coast, or at all events for certain periods, and that an equatorial current may account for the phenomenon. The difference between the Abrolhos Islands and the mainland may not however lie in the same direction at all seasons of the year. It is to my mind noteworthy that it is during the winter that we are sure of a certain higher degree at the Abrolhos than at Geraldton, and it is not the actual amount of difference that I regard as important but the fact that the temperature at the Abrolhos Islands is pulled up during the winter months, when it probably rarely falls below 20° C. Indications of a tropical current reaching the Abrolhos in the manner described, do not appear on the American Pilot Charts of the Indian Ocean, but the following quotation from Otto Krümmel's 'Oceanographie,' 2te. Aufl. ii. 675–6 (1911), shows that other investigators have noticed these West Australian conditions.

"Im Vergleich zur homologen Benguelaströmung ist die westaustralische nicht durch die gleichen niedrigen Temperaturen an ihrem Küstenrande ausgezeichnet, wie wir sie oben darlegen konnten. Wir haben als Ursache dieses Verhaltens die abweichende Konfiguration des australischen Festlands zu bezeichnen, welche einem von Norden und Nordosten her kommenden warmen Strom entlang der Küste einen Weg nach Süden und somit in den Rücken des Südostpassats gestattet. Dadurch ist also eine ausreichende Kompensation an der Oberfläche von Norden wie von Süden her ermöglicht; man kann schon aus dem Auftreten von Riffkorallen bei den Houttmanischen ($28\frac{1}{2}$° S.B.) auf dauernd warmes Wasser schliessen. Ein warmer Strom kommt insbesondere im Südsommer aus der Timorsee und, in den Buchten Nordwestaustraliens Neerströme entwickelnd, geht er nach Südwesten, um anscheinend bei der Dirk-Hartoginsel, dem westlichsten Punkte des Festlandes, nach Süden umzubiegen und nach dem Befund der Gazelle-Expedition 16 Seemeilen in 24 Stunden nach Südosten zu laufen."

We have seen that Saville Kent emphasized the fact that the marine fauna of the Abrolhos differed in an extraordinary manner from that of the adjacent coasts, and he accounted for this by the assumption of a current, the existence of which is now supported by a considerable amount of evidence. The Hamburg Expedition of Michaelsen and Hartmeyer did not visit the

Abrolhos Islands, but Michaelsen adds a note concerning them in a report *, apparently as a result of an examination of collections in the West Australian Museum. His report is somewhat singular for he makes no reference to the only marine biologist who had visited the islands, and adds: "An exact description of these islets and of their physiographic faunal relations has been given by Helms. After studying the zoological materials of the Abrolhos in the West Australian Museum in Perth, I can affirm Helms' assertion about the marine fauna of the Abrolhos." Now, the first mention of the tropical character of the marine fauna of the Abrolhos is due to Saville Kent. Helms states that this naturalist visited the islands but does not refer to his paper, and indeed does not enter into any discussion on the character of the marine fauna or on the southern position of these islands. Yet Michaelsen states that he can support the remarks of Helms on the character of the marine fauna, and then goes on to account for the tropical character of this fauna. His explanation includes an exactly similar theory to that propounded ten years before by Kent. This is put forward without even the temperature records that Kent had made, and without reference to Admiralty Charts for confirmation. We must consider in some detail the further remarks of Michaelsen to the effect that a "Kalter Auftrieb" rising from the depths of the sea may also explain the difference between the marine fauna of the Abrolhos and the coast.

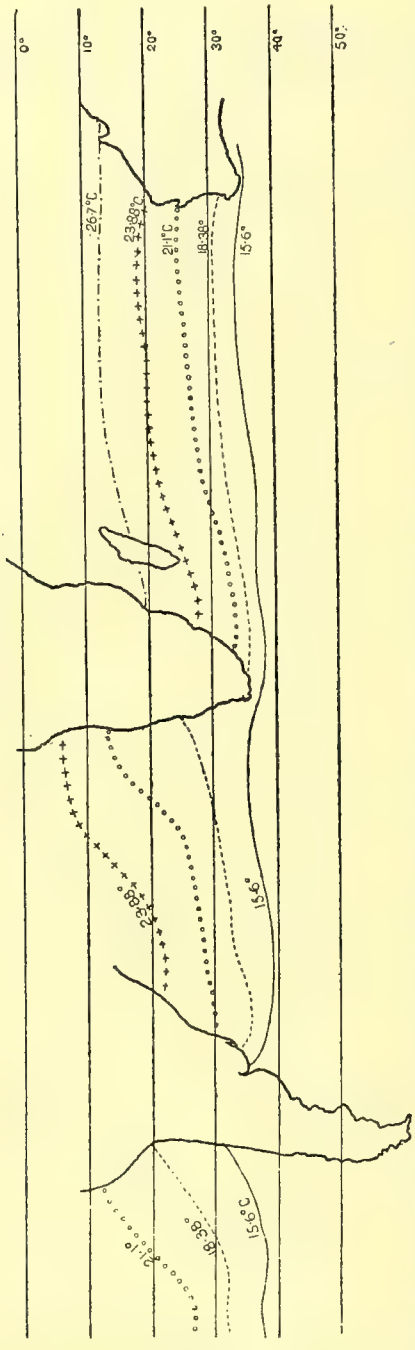
The term "Kalter Auftrieb" is used by the German hydrographers to denote the rising cold waters which are met with along a lee shore, and are due to the removal of the more superficial waters to windward. This phenomenon accounts very well in many places for a great difference in temperature between the coastal waters and those some little distance out, and excellent examples are to be met with in the Baltic Sea and the Sea of Azof, as well as along the coasts of some continents when strong offshore winds are blowing. This vertically moving colder water is also held to account for the lower sea temperatures in the Atlantic and Pacific Oceans along the Western coasts of Africa and South America in the region of the trade winds, one of the results of which is the well-known absence of coral reefs along the West coasts of these continents.

If, however, we examine the following diagram (text-fig. 4), which shows the position of certain isotherms between the land masses of Australia, South America, and South Africa, we shall see that there is a difference between the west coast of Australia and that of these other two continents.

"The inflowing and outflowing waters probably find their way not only through the wide and deep channels between the islets, but to some extent through the body of the reef, which in its upper portions would appear to be almost as open and pervious as a sponge."—*Judd.* "Materials sent from

* "Die Tierwelt Südwest-Australiens und ihre geographische Berichtegen." Mitteil. Geog. Ges. Hamburg, Bd. xxii.

Funafuti." Report of Coral Reef Committee of the Royal Society, Section X. p. 176 (1904).



Text-figure 4.

The mean annual surface temperature of 21·1° C. is much nearer the equator on the west coasts of South America and South Africa than it is on the west coast of Australia. In other words, the water washing the coast of West Australia is warmer than that washing the west coasts of South America and South Africa in the same latitude.

We really require much more data from this coast before theorising on the effect of such movement of water as a "Kalter Auftrieb." It would appear, however, from the following that Michaelsen's suggestions can scarcely hold good for the region under discussion. East winds are stated to prevail on the west coast of West Australia for a considerable part of each day. "These push the warmer surface water seaward, and so cause the rising of the colder bottom water to replace the driven water at the surface. The rising of the colder bottom water, 'the cold swell,' takes place quite close to the coast and of course influences mostly the line of the coast and its fauna. On the surface the originally colder water soon gets a higher temperature, so that by the time it has been driven by the east winds over the space between the coast and the Abrolhos it has grown warm." We shall refer later to the winds on this coast; let us look again at the sea temperatures. If a cold water upwelling, especially of any extent, takes place along the west coast of Australia it is caused by the trade winds (not an offshore local breeze), and it would probably occur along the edge of the

continental shelf and *not* against the coast. The water between the Abrolhos and the mainland is only about 20–25 fathoms deep. Now it is hardly likely that one would find on this shallow coastal strip of water lying over the shelf a much colder zone nearer the bottom consisting of water running in towards the land with a well marked layer of warmer water running out on the surface. The temperatures, so far taken by me, give no indication of such a state, the waters of the shelf appearing homothermic. It must be remembered that there is frequently a considerable sea running in this region, and with depths of only 20 fathoms it is likely that homothermic water will result.

The following figures are taken from those of the last Abrolhos Expedition. Unfortunately they are few because we were usually close to the islands working the lagoons or else to the leeside (the East).

Thursday, 28th October, between Wallaby and Easter Groups towards open ocean.

Surface	...	20·6° C.
15 fathoms	...	19·87° C.

Sunday, November 7th, between Easter Groups and Pelsart Group.

Surface	...	20·8° C.
20 fathoms	...	20·3° C.

Friday, October 22nd, outside Easter Group.

Surface	...	19·8° C.
Bottom	...	19·5° C.

Many readings were taken in the lagoons, but they are useless from the above point of view—the surface and bottom temperatures were usually the same except that the extreme surface layer, on an absolutely calm day, was often higher as a result of the direct heating effects of the sun.

If we examine the prevailing winds at the Abrolhos we shall see that there is less evidence still in favour of a warm surface current blown out from the coast accounting for the Abrolhos Fauna.

Winds, Geraldton District and Abrolhos.

Summer—From the middle of September to the middle of May, Southerly winds are characteristic.

Rest of Year—Winds variable, with occasional N.W. to W. gales of moderate force and of usually short duration.

Summer Winds—During the summer the Southerly wind blows almost without a break and resembles the trade wind in character and in force. In the early hours of the morning it is certainly in the form of a land breeze, but is E.S.E. to S.E. and is light. About 9 a.m. it hauls to the S. or S.S.W. and commences to freshen, blowing its strongest during the afternoon and continuing very frequently until after midnight. It then falls light and works back to the land breeze again. Very occasionally,

during the summer, the wind with a falling barometer comes away fresh from the E. to N.E. at sunrise, but it drops at noon and is followed by the Southerly as usual.

Winter Winds—During the winter the winds are variable. Southerly winds are frequent though of lighter force than those during the summer. N.E. winds are also of frequent occurrence in the mornings, but there is a calm or Southerly during the afternoon, or perhaps a strong N.W. blow. Taken altogether there is far less wind during the winter than summer.

Now, at the Abrolhos, 30 to 50 miles away from land, the winds are much the same, except that the land breeze *is not nearly so evident and often quite absent*. There is not much support here for a prevailing East wind blowing out the surface water. Further information may be obtained from actual observations of the currents. Here again I have had to depend upon information culled from the fishermen who are out at all seasons of the year. They state that during the winter, a southerly current is usually experienced between Geraldton and the Islands. Its velocity is about one knot per hour, but this may be increased with N. winds to 2–3 knots. This is quite in favour of the tropical current theory. During the summer southerly set has also been experienced, but as calms are very seldom it has not been noticed nearly so definitely.

Tides.

The tides on the West Coast of Australia present some great problems, and very little is known of these phenomena at present, although the question is of importance to shipping. For the greater part of the coast from the Leeuwin northwards (as far as Shark's Bay), the rise and fall of the tide is very small, the mean spring rise being only 2 ft. 6 ins. at Fremantle and Geraldton, and only 2 feet at Bunbury. At Carnarvon the mean spring rise is 5 feet, but in the north-west the conditions are very different, and a mean spring rise of 34 feet has been recorded at Derby.

The mean neap rise at Geraldton is only 1 ft. 6 ins.

It must not be thought, however, that tidal phenomena on this coast are only peculiar in that the amplitude varies enormously along the coast, and is so small at Fremantle and Geraldton as to be practically insignificant. The greatest problem is associated with tidal irregularity. Thus, at Fremantle the tides are usually diurnal, roughly 24 hours elapsing between the two high tides. Occasionally, however, for a succession of a few days, the tides become semi-diurnal. The diurnal tides are associated with irregularity, and it is extremely difficult to predict them with any accuracy.

At the Abrolhos, as at Fremantle, there is but little rise and fall of the tide, but it is of more use for collecting purposes than at the latter place, and seems to be of somewhat greater amplitude. We should say that the

mean spring rise was nearer three than two feet. On both occasions when we were at the islands the tides were diurnal, and it came as a surprise on our first expedition to find that not only was there but one tide every 24 hours, but that low water came at practically the same hour each day. On both expeditions low water occurred always between 6 and 8 a.m. The harbour master at Geraldton stated that during the summer months the tide at that port was usually high about 9 p.m., with low water at 9 a.m., whilst in the winter the converse was the case. Whether this be so or not at the Abrolhos is impossible to say. We can only affirm that all our shore-collecting was carried out in the early hours of the morning during the last week of October and the month of November.

Stokes gives the following rather surprising details which we can neither confirm nor deny; such conditions certainly did not prevail whilst we were at the islands. The high-water at full moon and change occurred at 6 p.m. During the night there was a short flood lasting six hours, the water rising seven inches, and a shorter ebb of only two hours' duration, the tide falling five inches. During the day, however, there was a flow of 8 hours 20 min., and an ebb of 8 hours 5 min., the rise and fall being 25 and 26 inches respectively. There were further variations at the different island groups. It appears quite certain that the tides are very irregular.

Rainfall.

No statistics exist, or are likely to exist in the future, concerning the rainfall at the Abrolhos Islands. The nearest figures that can be utilised are those for Geraldton, they will suffice to show the type of rainfall experienced in this region. The rainfall is stated in "points," 100 points equalling an inch.

Rainfall at Geraldton.

Year.	*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Total.*
1913	30	3	17	107	24	246	367	631	268	118	7	8	1826
1914	3	3	Nil	29	113	291	273	135	5	87	93	Nil	1032
1915	18	459	28	78	241	790	529	332	159	97	Nil	18	2749
Averages for the last 38 years.	16	27	33	87	272	454	392	301	135	66	25	13	1821

Note.—The figures indicate "points," one hundred points of rain equal 1 inch.

It will be seen that the average annual rainfall for the last 38 years is 18 inches. The dry months are October, November, December, January, February, and March, the average fall recorded for this period of six months being only 1·8 inches.

NORTH ISLAND.

North Island was only visited on our first expedition to the Abrolhos, and our observations have not been so detailed there as at the other places. This island does not appear to have been visited so frequently as the others, being due in all probability to its greater distance from the coast.

North Island is almost a square mile in area. It is not surrounded by smaller islets, and differs from the other groups we shall consider, in being without any real lagoon region. In fact, the part above water at all states of the tide rises from a coral flat which fringes it on all sides, but it is very much wider on the west than on the east. On the Eastern shore, a fringing reef lies quite close to the island, and a few breaks or channels occur where fishing luggers can obtain some shelter and anchorage in bad weather. The channels, which are very irregular, are about 5–6 fathoms in depth, with sandy bottoms on which large holothurians may be easily seen through the clear water. On the West side of North Island the margin of the reef lies just over a mile away from the shores of the island. No boat channel or lagoon exists between it and the shore. A broad reef-flat extends from the shore out to the reef-margin and is covered by a foot or two of water at high tide. One can walk out for the whole distance, but care must be taken, for the coral surface is rotten and full of holes, with larger hollows here and there. There are no living corals growing upon the surface of this flat. The same reef-flat extends north and south of the island for a greater distance and is continued as a submerged reef for a considerable stretch towards the Wallaby Islands.

The surface of the flat is covered with living *Vermetus*, and, as a matter of fact, this gasteropod is the common animal of all the reef-flats of this region. The shells puncture neat but exceedingly painful holes if anyone carelessly places an unbooted foot on such ground. The rock-pools swarm with young fish which must pass through their larval stages with some rapidity in such heated water (the temperature rises to remarkable points whilst the sun is shining). A blue crab, *Thalamita* sp. (probably *stimpsoni*, an Indian form), was very abundant in holes in this coral, and also the sea-urchin *Echinometra mathæ*. We shall meet with this species elsewhere.

North Island itself and the two large islands of the Wallaby Group are the only ones to attain any height above 8–14 feet. The highest point on North Island is 42 feet above sea-level. All this high ground of North Island consists of blown sand, which rises in the form of dunes quite close to the eastern shore margin. Other hills lie irregularly behind these, so that a distinctly high region occurs close to the eastern side. The height of the island falls off rapidly as the centre is approached. At the south-eastern corner of the island the margin takes the form of a low coral-limestone cliff instead of sand-hills, and the coral-reef flat, already referred to above, runs into the foot of this. As a matter of fact, in many places it is undercut by

the sea and overhangs very considerably (Pl. 14. fig. 6). This limestone conglomerate forms the margin of the island for a little distance along the western shore, but gives place to a sandy beach again as the northern shore is reached. The sand dunes are not so high here as on the eastern side. The coral limestone, which is exposed at certain places along the shore, can be traced inland and evidently forms the foundation of the island. Its surface is about 6 or 8 feet above sea-level, and it agrees in structure with that to be referred to later in connection with the Wallaby Isles. The central part of the island is quite low and flat, and only a few feet above sea-level (a salt lake, dried up at the time of our visit, occupies part of it). No rock exposures are visible once the shore is left, the whole being covered with sand which, as we have remarked above, is responsible for the height of the island above sea-level. The sand-hills are thickly covered with low halophytic bushes of a hard and brittle nature, and the terrestrial fauna appears to be poorer than that of the southern islands. The lack of fresh water is probably responsible for this.

Shore-collecting was not very successful at North Island, and as the other islands appeared likely to offer better opportunities for all-round work we spent very little time there. A number of specimens of *Heterodontus phillipi* were captured whilst we lay at anchor close to the shore, together with the Parrot fish (*Coris auricularis*, one of the Labridæ); Groper (*Acherodus gouldii*); Skipjack (*Caranx platessa*) and Buffalo Bream (Carangidæ). The latter looks very much finer than it tastes! A number of birds were noted and are enumerated in Mr. Alexander's report. Further reference will be made to the structure of North Island in the section dealing with the formation of the four islands. We may remark here that the wide expanse of reef-flat represents the result of erosion and that North Island will probably be cut down still further in the future.

THE WALLABY ISLES.

This group of coral islets is, in some ways, the most interesting of all, for it is on certain of these that the land fauna requires, as an explanation of its character, the assumption of land connection with the mainland of Australia. The group consists of two large islands (the East and West Wallaby Islands) together with a considerable number of small islets, many of which are not depicted at all on the small-scale charts. The East Wallaby Island lies really north-east of West Wallaby Island, from which it is separated by a very shallow channel about a mile across.

At first sight it appeared somewhat difficult to piece out the former history and the structure of the irregular collection of islands, reefs and lagoons of the Wallaby Group. It became much more clear after our second expedition, and I now consider that the group represents a stage in the development of an atoll form.

The two large islands form a kind of central mass. To the west of them lies a more or less shallow lagoon with an outer reef margin four miles or so to the west of East Wallaby Isle. To the eastward of the two Wallaby Isles is another lagoon with irregular coral reef bounding it, and small islets exist here and there where the reef rises above the sea-level. When sailing from the coast, one first sights the small islets of the reef on the eastern side, especially the rather long narrow islet (known as Long Island). The elevation of the Wallaby Islands, however, is sufficient to make them more conspicuous than is the case with any of the southern groups, so that in reality they are picked up from the masthead practically as soon as their eastern outposts. On our first expedition we ran into Turtle Bay (see map, text-fig. 5) first, as this shelter was easily reached from the open sea. After a few days we moved down Recruit Bay until a position was reached close to East Wallaby Island and almost opposite the channel between it and West Wallaby Island. On the second expedition we reached the Wallaby Group from the south, and after passing through the Channel close to the east side of Long Island (see map, text-fig. 2) we entered the lagoon and anchored close to the latter. Later on we changed to an anchorage of the former expedition in order to investigate the larger islands over again. Dredging was carried out north of the Wallaby Group between the East Wallaby and North Islands, in Recruit Bay, in the Channel east of Long Island, north of Morning Reef, in the lagoon, and some distance south of the group.

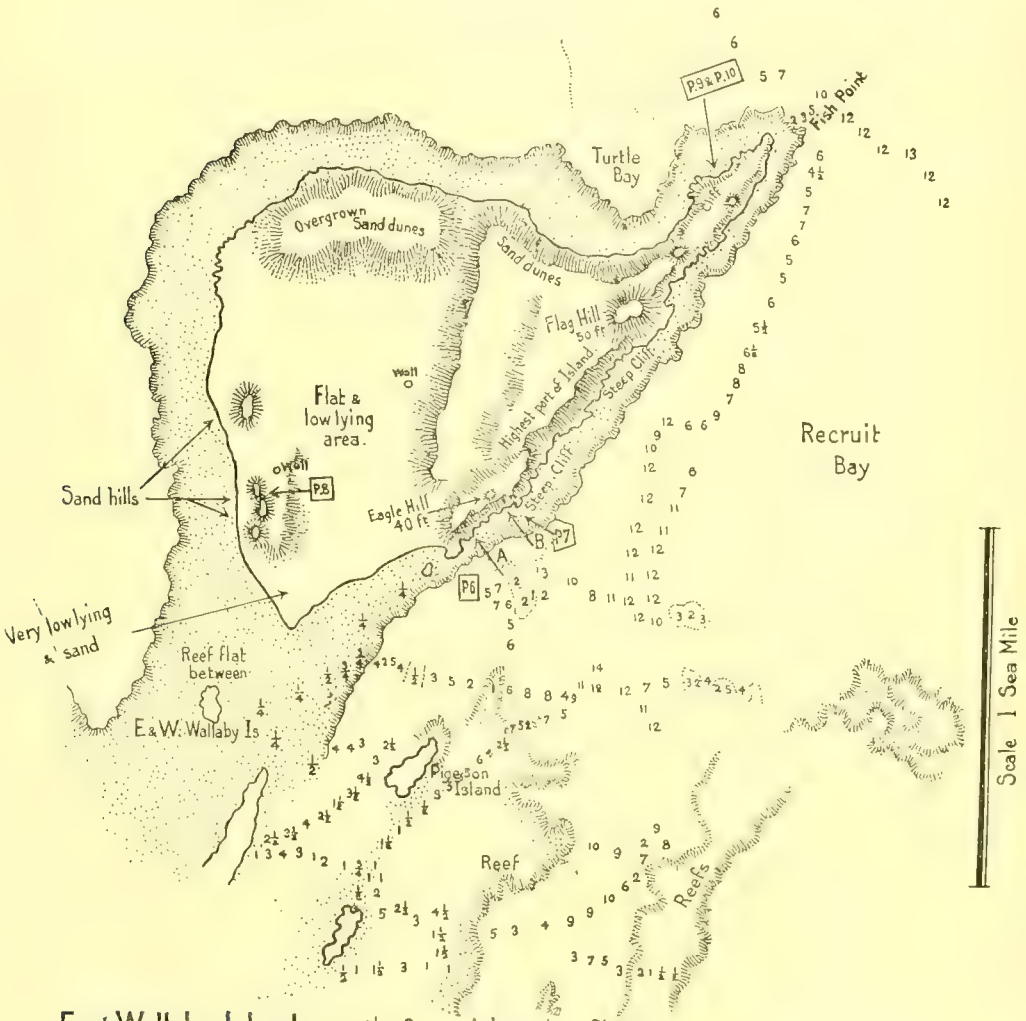
We shall consider the large islands first. The East and West Wallaby Islands appear to have been only recently separated, and the separation does not amount to much at the present time. The channel between them, which has a width of about a mile, is only a foot or so deep at high tide, and large areas are exposed at low water. It was regularly crossed by members of the party when they wished to reach West Wallaby Island, and if the tide were up and one were near the middle of the channel, with a fresh breeze stirring up the water, the situation was distinctly peculiar—one seemed to be standing in the centre of the sea! The floor of the channel is a flat of coral, here and there covered with a thin layer of mud, and bearing very distinct evidence of solution and erosion by the sea. The only additions are being made in odd places by the ever-present *Vermetus*. Beyond a few sponges, crabs, and some fish which abound in the large hollows of the flat, little is flourishing here.

East Wallaby Island.

The East Wallaby Island is about 1½ miles from north to south and a little more from east to west measured along the northern coast. Its longest diameter runs N.E. to S.W. and juts out considerably in the form of a north-eastern cape, Fish Point, which separates Turtle Bay from Recruit Bay. The highest part of East Wallaby Island is 40–50 feet high and this occurs right on the eastern coast, which is of some little elevation from the north-

eastern extremity down to a point where it turns more abruptly westward toward the entrance to the Wallaby Channel. By walking along the beach (which is a reef-flat) one can obtain a view of an excellent section showing the structure of the island where its height is greatest (see photo, Pl. **13**, fig. 4).

Text-figure 5.



East Wallaby Island. partly from Admiralty Chart.

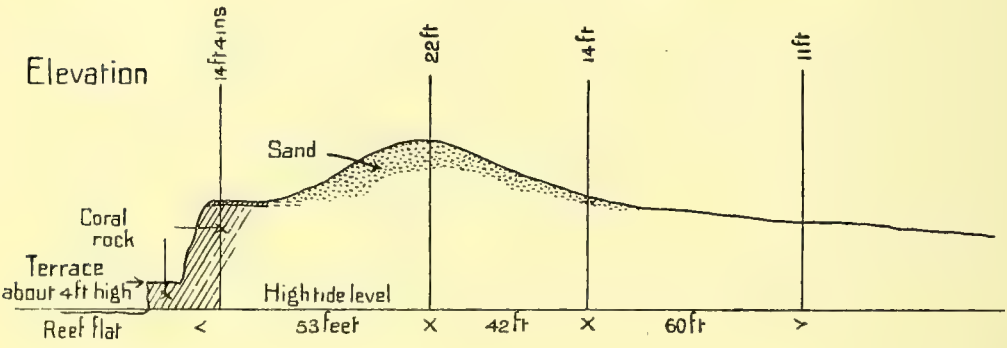
Reef flat area dotted.
A & B. indicate position of Sections illustrated (figs. 6 & 7).
Spots photographed indicated by letter P. & fig. no.

(Not all of the Photographs have been reproduced; those numbered 6 and 9 are now 4 and 5 on Plate **13**.)

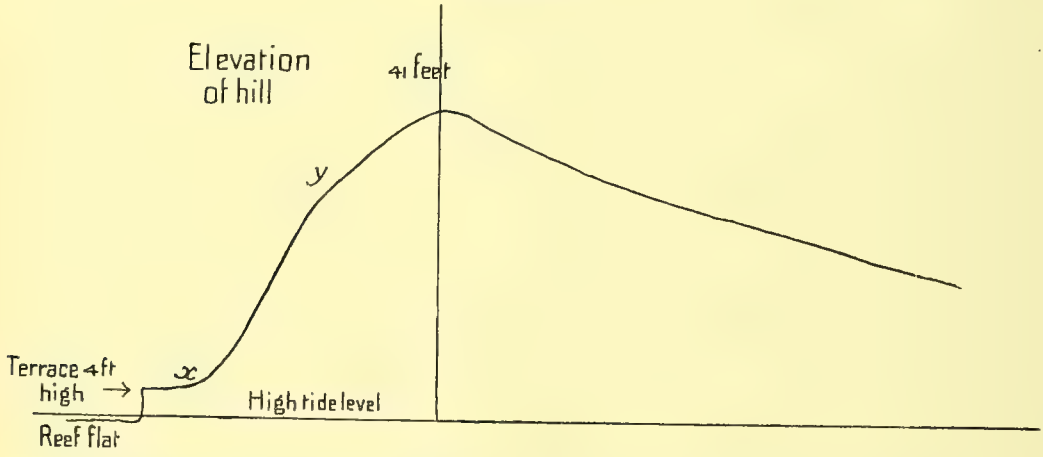
The two text-figures (text-figs. 6 and 7) indicate sections at right angles to the line of coastal cliff. They were taken about a $\frac{1}{4}$ mile apart. A coral-limestone cliff rises direct from the reef-flat and overhangs somewhat.

It is washed by the sea at high tide. This cliff is only from 4–7 feet high and presents a flat terrace of varying width, here only a foot or so, there a couple of yards (see text-figs.). From this, another cliff-surface rises to a varying height, 14 feet in the one case shown above, to probably upwards of 25 feet in the other. This is marked by another limestone surface, and it is possible to notice from the sea how this surface is not at the same height along the stretch of coast, but varies slightly. The complete height of

Text-figure 6.



Text-figure 7.



22 feet in the one section and 40 feet in the other is brought about by sand. On East Wallaby Island there is nowhere a thickness of 40 feet of coral above sea-level. Fourteen to twenty feet is probably about the maximum, and this is topped with sand. This condition, however, exists only along the margin of the East coast which runs in a straight line N.E.–S.W. If a traverse is made inland in a westerly direction (see map of East Wallaby Island, p. 151) the sand-hills become lower, until at a distance varying from $\frac{1}{4}$–$\frac{1}{2}$ a mile inland they disappear, and one reaches an almost perfectly flat area the

surface of which is limestone. No sand or guano hides the rock in this area now, but a few bushes are rooted in the crevices and cracks in the weathered limestone surface. This flat area occupies the greater part of East Wallaby Island, and sand-hills are not met with again until one reaches the extreme west and northern coasts. It might be expected that the flat area we have described with the coral-limestone surface would be as many feet above sea-level as the highest limestone exposed on the East coast. This is not the case, it is only about 10 feet above sea-level. It is only on the East coast of East Wallaby Island that any limestone higher than this is found. At the same time, the land rises once more on the western margin, so that the greatest heights are found on the East *and* West coasts. If, however, the eastern elevations are examined, they will be found to be composed entirely of sand, and the exposures are quite interesting. One of these eastern sand-hills is marked on the chart with an elevation of 35 feet—a well is indicated about 200 yards to the N.E. of it. Now just north of this sand-hill the wind has cut an extraordinary pass right through the hills and eroded it down to the limestone surface. The sides of the pass are perfectly vertical and there is abundant evidence that the whole is due to the wind. It is quite obvious here that the high land is due chiefly to blown sand.

The southern extremity of East Wallaby Island towards the channel is the lowest part of the island, and a sand-beach presents a marked contrast to the cliffs of the eastern shore. This sandy beach extends up the western shore to the north-western corner of the island where cliffs again appear, but only 3–4 feet in height and have a sandy beach at their base. The northern beaches are also of sand, with sand-hills behind, until Fish Point is reached on the east of Turtle Bay. Samples of the shore-sand from the north and west beaches of East Wallaby Island have been examined. The sand consists almost entirely of calcareous matter:—foraminifera, shell-fragments, coral particles, and echinoid spines. The foraminifera are all shallow-water forms, the predominant genera being *Orbitolites*, *Polystomella*, and *Peneroplis*. Other common forms are species of *Miliolina*, *Planorbulina*, *Globigerina*, and *Pulvinulina*.

A reef-flat exists all round the island, but it presents some points of difference on the various coasts. On the east coast (Recruit Bay), it is narrow, 100–200 feet or so in width, and extends to the base of the limestone cliff. It is covered with living *Vermetus*, and broken up with irregular hollows every here and there. To the south it forms a great expanse connecting East Wallaby Island with West Wallaby Island. On the west of the island the reef-flat is wider and extends out for at least a quarter of a mile from the beach, which, as we have already noted, is of sand. The same aspect presents itself again on the north-west, and there is much sand and weed growths here. A considerable quantity of decaying weed is conspicuous on the eastern and northern shores.

Let us return to the limestone. The best exposures illustrating its structure are to be seen in Turtle Bay on the west side of Fish Point (Pl. **10**). The cliff is collapsing here, but the surface is not weathered in the same way as at some other places where its structure is hidden. The limestone is a conglomerate of coral and mollusc shells (Pl. **10**). In parts it has quite a stratified appearance due to the presence of great flat coral colonies of a species common at present in the lagoons and allied to *Madrepora corymbosa*, if not this species itself. Between the corals is a hard mass of coral-mud, or secondary deposits of calcium carbonate, which cement everything together, and in which lamellibranch and gasteropod shells are imbedded. These shells show little or no signs of weathering or of abrasion. (See photo, Pl. **10**.) The most common of the molluscs are

Turbo pulcher, Reeve.
Conus magus, Linn.
Cytherea reticulata, Linn.
Septifer bilocularis, Linn.

There is every evidence of elevation to bring this coral limestone into its present position, and the corals appear for the most part to have grown *in situ*. We shall refer to this elevation later after describing West Wallaby Island.

It has been said that plutonic rocks occur on the Wallaby Islands. We have now made traverses across these islands in every direction, and we have also closely examined the wells which occur in one or two places. Nothing but limestone is to be seen anywhere, and we are quite sure that this rock only is present. There are no references to the actual discovery, or examination, of plutonic rock in the literature on the islands. What statements are made appear to be due to a casual remark which has been handed on by people who have not investigated, and in some cases not even visited, the islands.

West Wallaby Island.

There is no need to describe in any detail the structure of West Wallaby Island, for it is clearly the same as East Wallaby Island and obviously part of the same elevated limestone mass. West Wallaby Island is of irregular shape and is the largest island of the Abrolhos. From north to south the greatest length is just short of three miles. A few points of interest should be noted. The highest part of West Wallaby Island does *not* occur on the eastern side (*cf.* East Wallaby Isle), but on the southern mile of the western coast, and this elevated region is remarkably like that already described as occurring on the N.E. coast of East Wallaby Island. The highest point, for example, is again quite close to the shore, and a steep cliff rises at once from the

reef-flat. The cliffs themselves rise to a height of 30 feet, and the greatest elevation, only a little distance inland from these, is upwards of 50 feet.

This south-western corner of West Wallaby Island presents the finest scenic picture of the Abrolhos Islands, the cliffs are of rugged weathered limestone, and the margin of the outer reef swings in at this place until it comes quite close to the extreme S.W. point. The full swell of the ocean breaks, therefore, quite close to the island, and the waves rush across the reef-flat wearing deep pot-holes and excavating the coast. The photographs illustrate the type of coast at this point (Pl. 14. fig. 7).

It is very interesting to note that the mile of coast on the south-western shore of the island should resemble closely the stretch on the north-east of East Wallaby Island. Everywhere else on the Wallaby Islands the margin is much lower and with either sand or low-lying limestone.

Another point of great interest on the West Wallaby Island is the occurrence of a well-marked terrace on the western cliffs, about 6–8 feet above the level of the reef-flat. A similar terrace, slightly lower in places, is found, as already stated, on the N.E. shore of East Wallaby Island. We shall see later that there is evidence on the Abrolhos Islands of a recent uplift of 8 feet or so. The terrace represents the old sea-level before the last elevation.

A considerable part of the area of the West Wallaby Island is low-lying, being about 6 feet above sea-level. This applies to all the north-eastern portion (about a square mile) and the southern part of the East coast. The north-eastern region presents a surface which is largely flat limestone—resembling in appearance that photographed by Fryer on Picard Island in the Indian Ocean and described as "platin." It is covered with the usual stunted halophytic bush. In most places the limestone is completely hidden by a layer of guano and sand which looks as if inhabited by thousands of rabbits. The excavations are, however, due to mutton-birds, and as they are not very deep it is usual for anyone trying to walk over this area to fall through with one foot or both at every other step! The pavement-like surface of the limestone has been probably produced by successive solutions and redepositions of calcium carbonate by rain-water—the guano aiding. In past times a large quantity of guano was removed from West Wallaby Island and the ruins of an old camp and about 1½ miles of tramway still exist as relics, whilst a wooden pier runs out for a considerable distance on the west coast into the waters of the lagoon.

We devoted some little attention to the limestone exposed on West Wallaby Island, especially on the West coast where there was a thickness of 25–30 feet above sea-level. The lowest parts at this place consist of a compact rock, granular in appearance, fairly hard and without any traces of corals or molluscs. Microscopic examinations, kindly carried out for me by Professor Woolnough, of the University of West Australia, reveal the

fact that it is entirely composed of Foraminifera, Nullipore fragments, and Echinoderm spines, with a considerable amount of secondary deposition of carbonates round the individual grains. It is in fact an indurated beach-formation. No trace of land-derived sediment exists. It is this rock which forms the lowest part of the cliff, a layer of coral rock infiltrated with secondary carbonates appears at a higher level.

A reef-flat extends round the base of the West Wallaby Island. On the eastern side it extends out for some distance and smaller islets rise from it. This area will be dealt with again below. To the south the flat is narrow, and lies close up against the outer reef at this point. On the south-western side, at the foot of the high cliffs already described, the reef-flat is wide again, and here one meets with plenty of evidence showing that the flat has been formed by erosion. Pinnacles of rock are left standing, overhanging on every side (Pl. **14.** fig. 7), and great pot-holes occur on the flat itself.

The Reef and Smaller Islets of the Wallaby Group.

It is convenient after discussing the character of the chief land masses of the Wallaby Group to consider as a whole the remaining small islets and the coral reefs surrounding them. The "tout ensemble" is much more irregular than in the southern groups to be presently considered. A glance at the chart (text-fig. 2, p. 136) will show that a mass of coral reef exists several miles to the west of West Wallaby Island and protects a lagoon with 3–4 fathoms as an average depth in the northern portion. Towards the south-western point of West Wallaby Island this reef swings in, until it joins the reef-flat which fringes both the Wallaby Islands and forms the inner shore of the lagoon. Towards the same point, the broad lagoon becomes more and more shallow until only one or two feet in depth. The outer reef, against which the ocean swell beats, remains close to the coast of West Wallaby Island on the south as a fringing reef, and then leaves the S.E. point of the island in the form of another broad sweep which extends eastwards, but in a more irregular manner, and can be traced past Noon Reef and Morning Reef, where it turns northerly (text-fig. 2, p. 136). Inside the large expanse sheltered by the reef there are numerous coral growths and remains of islands, the whole thing being the result of solution, denudation, and active coral growth.

The two Wallaby Islands are connected, as we have already pointed out, by a broad and shallow reef-flat. This reef-flat extends over the shaded area in text-fig. 2, and several small islands rise from it, three of which (the more northerly ones) are shown on the map of East Wallaby Island (text-fig. 5, p. 151). The most northerly of these is called Pigeon Island by the fishermen, who like to enter Recruit Bay as far as they can and anchor with perfect shelter between Pigeon Island and East Wallaby. We camped on it several times. All the islands on this reef-flat agree in type. They are usually much longer than broad and with the long axis running nearly

north and south. They are all flat-topped, and possess vertical or overhanging cliffs about 8 feet in height (they are highest on Pigeon Island, 8–10 feet). Again, there is ample evidence that they have once been continuous. Pigeon Island is gradually becoming smaller, the cliffs overhanging in places for 20 feet or so forming caverns. Here and there great masses have broken off and are gradually being removed. The structure of the coral limestone of which they are composed is similar to that of the Wallaby Islands.

Whilst a glimpse of these islands with the lagoon waters presents certain pleasing features, they make a very uninteresting photograph. No palms or tall plants break the monotony, and the elevation of the islands is so small that from a little distance they appear simply as streaks in a photograph.

It may be taken for granted that all these islets have been cut away from one mass, and they are still being reduced in size by the action of the sea. The reef-flat connecting them together is all that remains of the elevated limestone of which they once formed part.

We are now left with one or two islets much further away from the Wallaby Islands on the outer reefs to the east, a narrow island known as Long Island by the fishermen and several islets not marked on the chart, some of which are only a few yards across. Many of these islands are obviously the result of blocks of coral heaped up by the waves, and their loose structure is quite different from the more compact limestone of the central mass. We are in fact dealing with structures more like the islets of the rim of a coral atoll.

Let us glance at Long Island, it being the largest islet in this situation. It is about one mile long and only a few hundred feet across. Its surface consists of small and loose coral fragments, and in fact the whole island is made up of such coral fragments. They prevail above all else, and one cannot consider coral as playing any subordinate part here to calcareous algæ, molluscs, or other calcareous structures in the formation of this mass. In places, the weathered fragments have been more or less cemented together to form a more definite kind of conglomerate. I consider that a slight elevation (not more than 6 feet) has played some part in the formation of Long Island as well as the heaping up of the coral fragments by the waves. The straight line taken by the reef on which the land stands is no doubt due to the current, which scours the eastern side, and has produced the channel referred to later.

A small lake exists at the northern extremity of the island and there are one or two other similar depressions at other places. We shall see that these are quite common on the islets of the rim of the Abrolhos Groups. This is rather an interesting point, and I have found it very advantageous and informing to compare the descriptions given by Stanley Gardiner of the "faros" of the Maldives with these islands of the outer rim possessing lakes

or lagoonlets. The water of the lakes is salt, and often disappears altogether at low tide. In other cases it is permanently present, and deep, but rises and falls with the tide outside. One in Long Island is only a few yards across, the banks are of coral conglomerate and loose blocks, and the floor of the lake or lagoonlet of coral with a deposit of mud. We shall refer in greater detail to the formation of these lakes when describing the same on the islets of the Easter Group.

Mention must be made here of the channel to the east of Long Island. It is very much used by fishing boats passing north and south, for it has a depth of 20 fathoms, and that quite close to Long Island itself. The channel seems to have broken through the reef, cutting off Morning Reef to the east of it from the coral masses on the west. Perhaps Long Island itself owes its formation to the development of this channel. As one would expect from the depth, a strong scour runs through the channel which bears every appearance of erosion. We dredged several times here and with excellent results.

Nothing more remains to be said about the reefs except that coral growth is active at the present time in the lagoons wherever the water appears to be free from mud. To the north-west of the coral marked Noon Reef on the chart is an expanse of water almost completely surrounded by coral reef. It can be entered by a channel to the west of Long Island, and by another one to the S.W. indicated by the arrow on the map, text-fig. 2, p. 136. This expanse of water is called " The Lagoon " by the fishermen (no other area is spoken of as lagoon by the fishermen anywhere in the Abrolhos Group). Depths of 6–12 fathoms occur, and the bottom is almost everywhere of coral. We investigated this area with the motor dinghy on many occasions, and were always delighted with the gorgeous growths of coral seen perfectly through the clear water. The most abundant coral is a species of *Madrepora* with a most beautiful blue-purple colour. This occurs everywhere, rising from the bottom in the form of great " shrubs." The more compact corals like *Meandrina* and *Astræa*, etc., do not seem to flourish here. *Pocillopora* is common in places. We have never obtained a *Fungia* at any of the Abrolhos Islands, and have seen no traces of such, not even fragments. Several times we tried the dredge in these lagoons and pulled it forcibly over the bottom, tearing away the more delicate corals at the risk of losing the dredge and cable, but we never obtained anything but coral and the small crustacea and worms which live in the crevices.

It would seem to us that the outer margins of the coral reefs fringing the Wallaby Group are extending seawards by active coral growth, at least in places, but that such growth is very slow. In the lagoons we see coral growth in certain areas, and sandy deposits with no coral growth in other parts. Here active solution and erosion is taking place, whilst there we find that coral growths are forming, or coral fragments are being heaped up by

currents and wave action. In the latter case small islets are formed and are often capped with a little sand. They only rise perhaps one foot above high-tide mark and are known by the fishermen as "Sandy Islands."

The Fauna of the Wallaby Group.

The name of the group suggests the first member of the fauna that deserves mention. The Wallaby *Macropus eugenii*, Desm., occurs on both East and West Wallaby Islands and in very large numbers, especially on the West Wallaby Island. I have seen far more individuals in one afternoon at these islands than of all species of marsupials seen on the mainland in three years! Some surprise was exhibited last year when I stated that four were shot on our first expedition without moving from the one place—one shot having killed two. On our second expedition we beat this by actually catching four specimens alive, by merely running them down! It is no uncommon sight to see half a dozen leaping before one at the same time. Naturally it is a point of the greatest interest to find fifty miles away from the coast, on a small coral island with only halophytic bushes, an animal of this kind in such large numbers. The large Wallaby Islands are the only ones inhabited by a marsupial. Traces of other mammals also occur, and a much decomposed rat was found (and left) in one of the water-holes on West Wallaby Island. Reptiles abound on these islands and were even common on the smaller ones which we have already referred to as rising from the Wallaby Reef flat. One of the most interesting is the Carpet Snake (*Python spilotes*), which occurs in very large numbers on West Wallaby Island. We could hardly ever walk down the two miles of the old guano tramway on the occasion of our first expedition without meeting several specimens lying across it, and usually they averaged about 7 feet in length. They were very sluggish. Curiously enough we did not see one in 1915; probably they hibernate in winter, and the winter of 1915 was particularly severe and extended well into October. No specimens were met with on any other but the West Wallaby Island. Two other species of snakes are supposed to occur in the Wallaby Isles, one of which was seen but not captured. Reference to the Lacertilia will be made in Mr. Alexander's paper on the Vertebrates. Seventeen species are recorded altogether from the Abrolhos Islands, and probably most of these occur only on the West and East Wallaby Islands. Two or three species are common on the smaller islands of this group, but the larger southern islands of the Pelsart and Easter groups have only one or two. Two species of Amphibia, frogs, are recorded from the islands, but we were unsuccessful on both occasions in finding any. On our second expedition we thought we should be more successful owing to the wet winter and our earlier arrival at the islands. We failed, however, to see any trace of them.

Several species of birds were nesting on the Wallaby Islands, and an account of the species recorded is given in Mr. Alexander's paper. The following remarks may be made here in reference to the photographs taken by the author. A large number of birds had congregated for nesting purposes on the west shore of the West Wallaby Island, several species occurring together. At one place there were several hundred nests of the Pied Cormorant (*Hypoleucus varius hypoleucus*, Brandt), all built of broken twigs and branches from some neighbouring bushes, and erected in close contact on the sandy shore. Our arrival was the signal for the departure of the birds, but the less shy Gulls, undisturbed by our presence, took the opportunity of feasting upon the eggs. Close to the Cormorant colony, Caspian Terns, Pacific Gulls, and Silver Gulls were nesting. The eggs were simply laid in slight hollows in the sand amongst stray pieces of mollusc shells. Reference has already been made to the Mutton-bird excavations. The birds must occur in thousands on the Abrolhos Islands wherever the rock is covered with sand in which they can burrow.

Several species of insects were captured on the islands, but the collection has not yet been worked up. The ant keeps up its West Australian reputation and is present everywhere, on the smallest islands as well as on the larger.

The Marine Fauna of the Wallaby Group.

The first place to be examined was Turtle Bay on the north of East Wallaby Island. The bottom was for the most part sandy with groves of Algæ, species of *Codium* being particularly abundant. *Zostera* also occurs here in large quantities. Except for a few Amphipods, both Algæ and *Zostera* were very barren. The shore sand contained a large percentage of Foraminifera of which *Orbitolites* was the most common. The very characteristic *Heterostegina* of the Ceylon sands appeared to be absent altogether. Nothing of particular interest was obtained on the reef-flat on the east side of East Wallaby Island. *Vermetus* was very abundant, a few sponges and crustacea occurred, and the coral limestone was bored by *Lithodomus* and Gephyrea. We used our chloride of lime for capturing fish in the rock-pools with some success here, but unfortunately our work was cut short by bad weather which caused so much disturbance of the water on the reef-flat, that it was impossible to poison the fish—they moved with the waves to other pools! Our best shore-collecting was carried out on the lagoon side of a small island (loose coral fragments heaped by waves) on the outer reef, about $1\frac{1}{2}$ miles to the east of the extreme S.E. point of West Wallaby Island. A long spit composed of small blocks of coral runs out from this island and is entirely submerged at high tide. The lagoon bottom to the north of the island was of sand, but with very fine growths of coral here and there, the two species most abundant being the

purple *Madrepora* already mentioned, and tree-fungus-like growths of a species allied to *M. corymbosa*, forming great flat expansions 3–6 feet across. Several large species of Holothurians abounded on the shore of the island, and could be picked up by wading. Anemones, Ascidians, and Sponges (calcareous and siliceous) abounded, and several Turbellaria were captured under the stones. In fact we were able to make a very good general collection here. A better place still on our first expedition was the eastern shore of Long Island. The beach consists of large coral slabs thrown up by the waves, and at low-water mark almost each slab was covered on its under surface with a gorgeous array of organisms. Rarely have I met such variety and colouring. A straggling brilliant lemon-yellow sponge was one very evident specimen. After turning several stones over and noticing what appeared to be pieces of this sponge falling off, it was discovered that the falling pieces were nudibranchs resembling the sponge in both colour and general appearance. The species belongs to the genus *Notodoris*, this being the first record for the genus on the Australian coast. It was instituted by Bergh for a single specimen of *N. citrina* from Rarotonga. Two other species have been made by Eliot for specimens from Zanzibar and the Maldive Islands. All three are yellow in colour. It is stated in Eliot's report that nothing is known of the habits of these animals and further—"With Mr. Gardiner's specimen is a piece of hard yellow sponge. There is no note, but as the colour and consistency of the sponge closely resemble those of the Nudibranch it is highly probable that the latter frequent it."

It is interesting to find that this is actually the case and in an entirely different region. Our specimens were always found associated with the sponge. The Nudibranch moves about very slowly, so far as could be observed, and apparently lives in the dark under coral blocks.

A large number of different species of Brachyura occurred on the Long Island shore, amongst which may be mentioned the characteristic species *Liolphus platissimus*. This peculiarly shaped and beautifully marked crab was exceedingly common. It is an Indian form. Several specimens of the Stomatopod *Gonodactylus chiagra* were also obtained under stones.

Small macrurans of a species as yet not identified were common, and specimens of at least two species of *Alpheus* were captured. The Echinoderm collection contained chiefly large crinoids and asterids. The gorgonids were represented by one species.

On the western shores of West Wallaby Island collections were also made on the reef-flat. Five or six species of anemones were to be seen here in great numbers. The most abundant molluscs were *Astralium* sp., with beautiful blue operculum (the species is common on the coast both north and south of the Abrolhos latitude), and *Vermetus*. Large numbers of the Siphonophore, *Porpita*, came in over the reef one afternoon.

Hauls with the dredge were made several times just outside Recruit Bay, with a depth of 20 fathoms. We finished up to the N.E. with a sandy bottom and an abundance of seaweed. Large hauls of sponges were made here, and compound Ascidians and Echinoderms, including *Synapta* sp., were present in considerable numbers. Echinoderms were always well to the fore so far as individual numbers were concerned. Crustacea were only moderately represented, being chiefly Brachyura and Alpheids, which abounded in the crannies of the coral rocks brought up in the dredge. Macrura were not common on the whole.

A few dredge hauls were made east of Evening Reef in a rather rough sea. The bottom was of sand and small fragments with much weed. A few Echinoderms were obtained, including a fine *Astrophyton*.

THE EASTER GROUP.

The Easter Group differs in several respects from the group of islets we have just been considering. In the first place it has much more the aspect of an atoll with an island in the middle of the lagoon, the total area of the atoll measuring about 35 square miles.

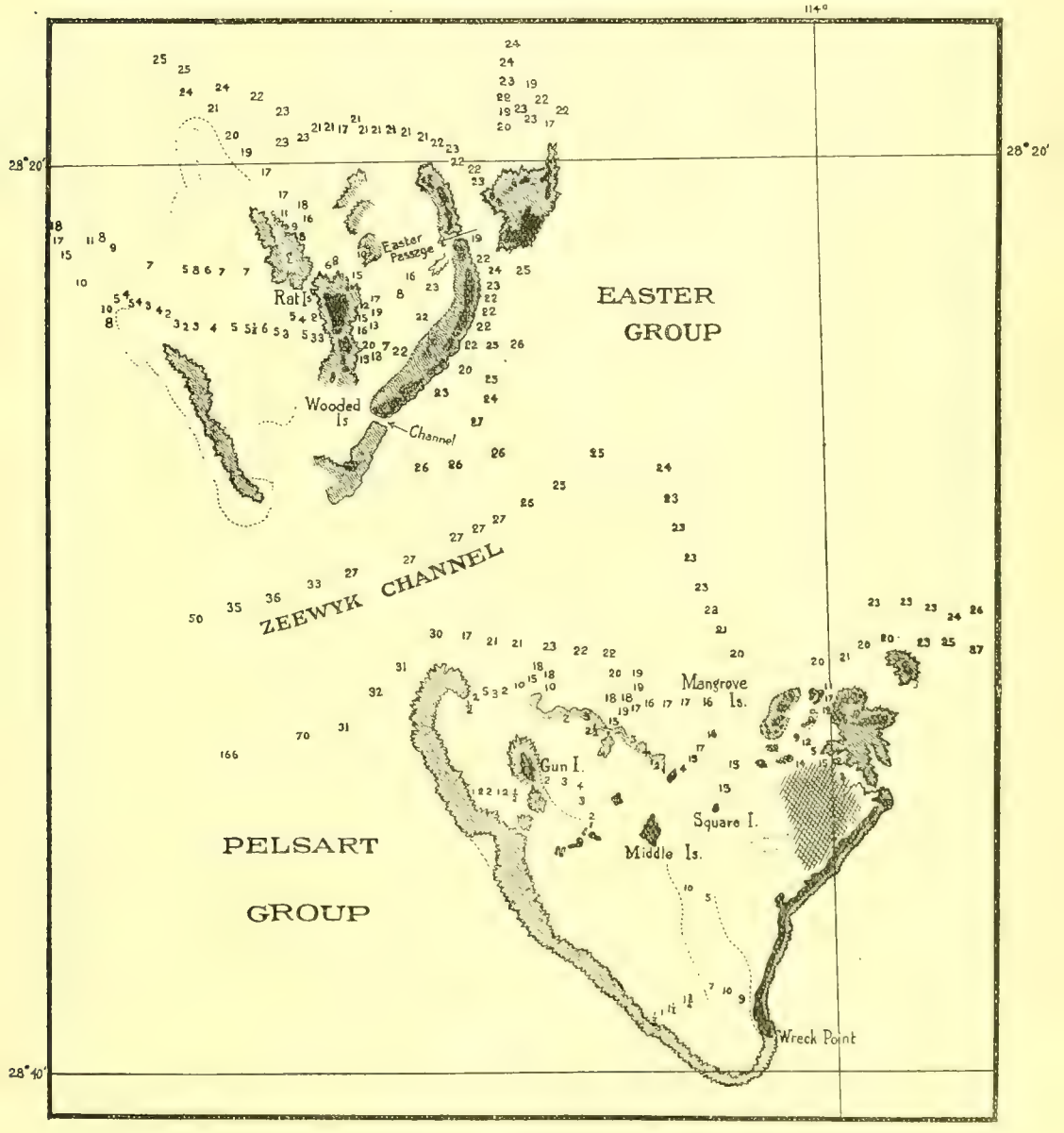
The central island is Rat Island, (2 or 3 small islets which lie to the south and are separated by narrow channels a few yards across—dry at low tide—may be considered as part of it), and a glance at the chart (text-fig. 8) will show that the surrounding reefs encircle it in quite a regular manner at a distance varying from 2–5 miles. A gap occurs in the reefs to the south of the group, and they are not well developed to the north-west and north. In other words, the larger entrances to the lagoon are to the north and north-west. We shall see later that this agrees with the Pelsart Group. It will be remembered here that encircling reefs were similarly best developed to the south of the Wallaby Group, whilst the chief entrances to the lagoons opened to the north.

The encircling reef to the west of Rat Island does not bear any islets above sea-level at high tide. There are several islets, however, on the eastern rim forming a chain upwards of eight miles in length. This development also agrees perfectly with the character of the more southern group of the Abrolhos. Each group of islets is evidently being modelled by the same forces and conditions. The depths of water in the lagoon of the Easter Group range from 2–22 fathoms, there being quite considerable depths on the eastern side of Rat Island between it and the islands of the rim. Before considering, however, the lagoon and the coral reefs, let us glance at the central islet—Rat Island. This is the largest island of the Easter Group, but it is smaller than either of the two Wallaby Islands, being only a little over $\frac{3}{4}$ mile long (from N. to S.) and not half a mile broad.

The small islets to the south of Rat Island are four in number and are

obviously part of it. They rise from the same reef-flat and show distinct signs of having been cut off comparatively recently by erosion. All agree in formation and in appearance. Rat Island itself is flat-topped and almost

Text-figure 8.



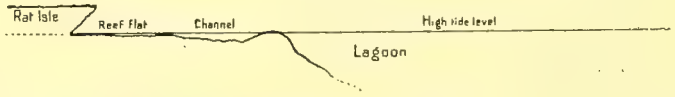
everywhere exactly 8 feet high. The margins take the form of an undercut cliff, which overhangs very considerably in most places. Here and there are great masses which have fallen and now are being removed by the sea at

high tide. It has been turned over pretty thoroughly by the guano workers, so that there is little material left over the rock and one can examine the latter quite easily at any point. It is a coral limestone which has been so compacted that a very hard homogeneous mass has been produced. Professor Woolnough, who kindly made sections of this material for me, states that it is coral rock completely infiltrated with secondary carbonates and completely solid. I consider that the coral limestone of the central islets is slightly older than any rocks exposed as part of the outer reef islets.

The surface of the island is covered with the usual bushes standing about four feet high at most. Many introduced plants occur, the result of the residence of guano workers and fishermen. Numerous holes due to subaërial denudation exist, and two or three of these may be termed wells—they probably contain fresh water throughout the year. It is neither satisfactory, nor plentiful enough, for the few guano workers at present on the islands, who have all their supplies brought in tanks from the mainland.

Surrounding the whole of Rat Island is a reef-flat which is increasing in width, for the island is being rapidly eroded to this level. Close to the edge of the reef-flat, just before the deeper waters of the lagoon are reached, is a small boat channel about four feet deep. The section (text-fig. 9) shown illustrates this character.

Text-figure 9.



The rim islands of the Easter Group and the eastern area of the lagoon have been very closely examined—more so than other parts of the Abrolhos. There are upwards of a dozen islets of varying size, some of which can hardly be said to be separated from one another, for at low tide one can cross without wetting the feet, whilst at high tide it is quite easy to wade across. Others are, however, separated by deeper channels.

A channel, with 6–10 fathoms of water, exists where we entered the lagoon of the Easter Group (see chart), called Easter passage by the fishermen. Another one occurs just south of Wooded Island where the charts are marked "Channel reported." Between these two passages there are no deep channels, and one could pass more or less easily from islet to islet, a distance of roughly 5 miles. All these islets agree, as might be expected, in character. They are largely composed of heaped up blocks and fragments of coral. For the greater part these still remain loose and uncemented, or but slightly so. In places, however, a more solid limestone is exposed, as for example on Wooded Island and on the southern end of the islet immediately to the north of it. It is a conglomerate composed chiefly of weathered fragments of coral. The island immediately south of the Easter passage is also largely composed

of cemented coral fragments. At no place is the height of these islets of the outer rim as great as that of Rat Island (viz. 8 feet), and, as we have already pointed out, where the land does consist of cemented coral fragments the limestone produced is nothing like so hard or compact as that of Rat Island.

The eastern beaches of the islands in every case consist mainly of loose coral blocks, and in places one can see how these are piled in such a manner as to form very definite strata by the regular heaping of these blocks on the northern shore of Wooded Island.

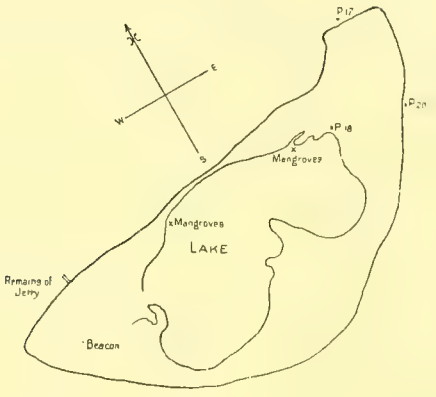
In many places, perhaps in most, the surface of the coral blocks is covered with sand and guano. The surface of Wooded Island appears to be of quite clean coral fragments with a sparse covering of shrubs and *Mesembryanthemum*. I find, however, that the guano workers shifted some tons of guano several years ago from the island, and it is quite probable that they also cleared this material from the general surface.

There is a great tendency towards the formation of small or large lakes on these islands. This has proceeded to such an extent that Wooded Island has quite a character of its own ; a lagoon of such extent exists that the island might be called a miniature atoll. Moreover, this internal lagoon attains a considerable depth, for we sounded six fathoms in the centre. The water of all these hollows, whether small or large, is salt, and furthermore is in communication with the sea. Some idea of the mode of formation of the comparatively large lagoonlet on Wooded Island can be deduced from the smaller ones on the other rim islands. Thus, on the island immediately south of Easter passage is a pit with six feet of water in it at the deepest part. It is 58 feet wide across the widest part and 100 feet long, being roughly oval in shape. The sides of this hollow overhang and are obviously being eroded at the water-level. On one side a large slab of the cemented coral formation has broken off owing to this undercutting. There is ample evidence that these hollows are produced by the combined action of percolating sea-water and the weather, and in most cases *after* the formation of the land. By means of a few simple surveying instruments, we were able to show that the level of the sea-water within the hollow was either the same as that of the sea-water outside the island, or within a foot or so of it. Whilst the tide was rising, the level of the water within the hollow was somewhere about one foot below the sea-level. When the tide was falling, the level of the water within was higher than sea-level by about the same amount. The communication with the sea is therefore evident, and also the "lag" due to the resistance experienced by the percolating water.

Another much larger "lake" existed on the island we have just referred to, but it is not so large as that on Wooded Island. In character it is similar to the one already described, and it is obviously produced by the extension in area of such a small one, or the union of several small ones.

The floor of the hollows referred to on the more northerly island was of hard coral, with a small deposit of calcareous mud. *Ulva* and one or two species of mollusca abound in the water and a fish (a species of Cobbler) was captured in the smaller cavity. It is impossible to say whether these fish could pass in after having attained the size which they measured—7 to 8 inches. They may have reached the interior at a much earlier stage and developed there. In any case they must have passed at some stage through a considerable length of subterranean channel, for it is very unlikely, if not impossible, that human hands could have placed them where they were found.

Text-figure 10.



We have surveyed the rim islet known as Wooded Island and a rough map of the same is given (text-fig. 10) which shows the extent of the remarkable lake or "velu." * Now this velu is of very considerable depth (6 fathoms), and from certain points of difference between it and the smaller ones mentioned, and also from the fact that very similar "holes" exist on the reef-flat in the lagoon close by, I am inclined to believe that this lagoonlet or "velu" had developed before Wooded Island rose above high-tide level. In any case, the original velu has been enlarged since, by erosion similar to that taking place in the smallest pits, and probably guano workers have shifted deposits from it where the mangrove trees are found.

One very frequently finds mangrove trees growing in these hollows—in fact they are restricted to this position on the islands of the outer rim of the Easter Group. Several small thickets occur on the shores of the velu of Wooded Isle, and a thicket occurs in a similar depression (which, however,

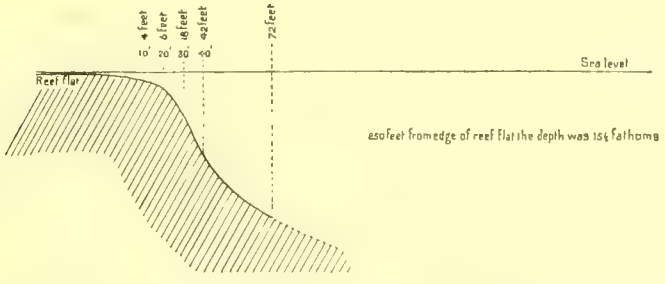
* The term "velu" is used by Stanley Gardiner for the lagoonlets or deep pools sometimes found on the islets of the Maldive atolls. I have not used the term throughout for the hollows referred to above, owing to an uncertainty as to whether it would be correct to apply it here. The lagoonlet on Wooded Island seems, however, to agree both in formation and appearance with the "velus" of the Maldives.

is without sea-water at any state of tide) on the island immediately north of it. This latter hollow (Pl. 12) has almost been filled up with guano deposits resulting from the hosts of the Lesser Noddy, which breeds only on Wooded Island and the adjacent one. The amount of guano produced by the birds is so great that it is actually causing the death of these mangrove trees on the northerly of the two islets, and quite half the thicket consists of leafless and bleached branches. The nests of the Lesser Noddy are only to be found in the mangrove trees. Since the guano workers meditate an attack on this deposit, and their working months coincide with the breeding season of the birds, it is quite possible that the Lesser Noddy may leave these islands in the future.

The Lagoon and Submerged Reefs.

The usual reef-flat occurs round the islets of the eastern rim. In fact, this is a continuous structure running at least from Easter passage to the passage south of Wooded Islet, and the islets are only elevations upon it. On the seaward side the reef-flat varies in width, but it has the same character throughout. The surface is fairly smooth, not eroded leaving sharp points, as in some places in the Wallaby Group, where it is more exposed to still water and rain than to the constant wash of the sea at high tide. Large hollows occur here and there, and form shore pools at low tide in which animal life abounds. As a matter of fact, this reef-flat was probably our best shore-collecting ground in the whole of the Abrolhos. On one occasion the sea was calm enough for us to examine the outer margin of the reef from the motor dinghy. At the particular place visited the reef-flat was about 100 feet wide. It rose slightly, not more than a foot, at its extreme margin and then descended to a depth of $15\frac{1}{2}$ fathoms in

Text-figure 11.



100 yards. It was not easy to fix our position and make soundings, being shorthanded, and there was just enough swell to make very careful handling of the boat a necessity, especially when near the edge of the reef-flat; some figures were obtained, however, and the diagram indicates the nature of the slope.

Corals were growing actively on the outer edge, and there is evidence that the reef is extending seawards although but slowly. There are signs that the islands of the outer rim on the eastern side of the Easter Group are becoming joined up. There was certainly a deep channel at one time between Wooded Island and the one immediately north of it. At least I judge so from certain peculiar holes and channels amidst the reefs in the lagoon at this point. Now, one can walk across even at high tide, although if a strong wind blew from the east it might be difficult. We shall see later that in the Pelsart Group, which seems to represent a stage to which the Easter Group is leading, there are very few channels indeed and a single long island forms the eastern rim.

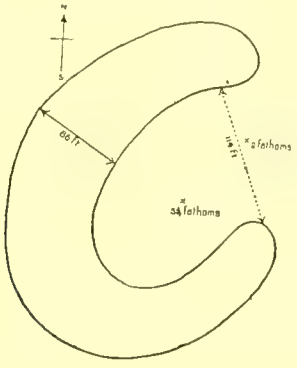
The lagoon reef-flat differed in character from that of the seaward side. In some places it was covered and hidden by sand or mud. In other places it was eroded in such a way as to be honeycombed everywhere, leaving but rotten coral, so that one had to be prepared when walking for at least one's foot going through. This was the case along the lagoon side of Wooded Island. Usually the reef-flat ended with an abrupt drop to the depth of the lagoon, instead of the slope to the sea-bottom which is seen on the outside. In some places, as a matter of fact, it overhangs. There were luxuriant coral growths along the lagoon edge of the reef-flat on the shore of Wooded Island, the more massive corals being present as well as several species of Madrepore, *Pocillopora*, and *Montipora*, but I do not think the reef-flat is extending lagoonwards at this point. Coral growths occur on the floor of the lagoon between Wooded Island and Rat Island, although not very luxuriant, and often nothing but dead fragments come up in the dredge. North of this latter region, *i.e.* between the islets immediately north of Wooded Island and Rat Island, the bottom of the lagoon consists of fine impalpable coral-mud, and dredge hauls were exceedingly barren. Further north still, between Rat Island and the island immediately south of Easter passage, luxuriant growths of coral occur once more, and in many places submerged reefs rise sufficiently high to be a menace to boats drawing 8 feet of water. One of these reefs, situated just to the left after entering the lagoon by the Easter passage, was rather interesting, and some notes may not be out of place here.

The reef in question rises up to the surface so that it is exposed at low tide. It is ring-shaped in form, with a broad opening on one side—that directed N.E. towards the nearest island of the outer rim. The sketch given in the text (fig. 12) indicates roughly the form of the reef, its dimensions, and the depths of water about it.

The bottom of the small enclosed lagoon is about 30 feet deep, and living coral abounds. It is also to be found on the floor of the entrance, and along the outer margins of the reef. It would appear that this structure resembles the "faros" of the Maldive Islands. It has developed by active coral growth from the floor of the lagoon, and it has taken up its present form as

a result of natural phenomena related to the growth of reef-building corals. Neither elevation nor subsidence are required to account for it. The only other possible explanation is that this ring-shaped reef is all that remains of a former mass perhaps at one time part of the outer rim islets some distance away from it. In that case erosion would play a more prominent part in the explanation of the present form, but would be governed by phenomena of normal coral growth. One can find other cases in the Pelsart Group where

Text-figure 12.



small coral growths are taking the form of miniature atolls, and neither subsidence nor the heaping of debris by waves and currents are responsible for the general architecture of these structures. Just as the one mentioned above occurs where coral growths are most luxuriant in the Easter Group lagoon, *i. e.* near its northern end, so in the Pelsart Group the northern open side of the atoll is the site of the greatest lagoon coral growth. In the latter case it is obvious that the general trend of water in the lagoon is from south to north, and the water is more free from sand and debris to the north where the lagoon is open to the sea.

Faunistic Notes on the Easter Group.

No large mammals occur on Rat Island except those which have been introduced, and mention has already been made of the cat which was introduced by the guano workers to keep down the rats.

The island has been noted by many ornithologists for the vast number of Noddy Terns which are found regularly every year during the months of October and November nesting upon the bushes. The nests are practically nothing but "stations" on the tops of the shrubs where the birds lay their eggs (Pl. **12**). Very often one meets with shrubs almost covered with the nests of these birds, the owners refusing to leave them when disturbed, unless actually pushed off. Large numbers of Sooty Terns also nest

on this island, but they prefer the ground just below the bushes. They are more timid than the Noddy Terns, and leave their nests on the approach of an intruder.

Mention has already been made of the Lesser Noddy which inhabits the mangrove trees of Wooded Island and the islet to the north of it. In the case of the latter, the mangrove thicket presents a curious appearance at the breeding season. The branches of the trees are covered with picturesque nests of seaweed, the straggling ends of which hang down; the birds are not at all shy, as may be guessed from the photograph (see Pl. **11**).

Reptiles are much less common in the Easter Group than on the islands of the Wallaby Group, and no snakes are found. Two small species of lizards were seen on Rat Island but not captured. Rat Island was one of the few places where we were troubled with Diptera—another relic of human occupation.

The reef-flat surrounding Rat Island did not prove to be a very good collecting ground. *Vermetus* was common as usual, and rock pools containing small fish and some crabs and Macrura were abundant. A living specimen of *Physalia* was captured in one of them, having drifted in with the previous high tide. Corals and gorgonids occurred on the submerged blocks of the little jetty which runs out for a few yards on the north of the island. Wooded Island coral flats—both the lagoon and seaward flats—proved extremely interesting, and were the home of a rich shore fauna. The margin of the lagoon flat, which as we have already pointed out presents an almost vertical or overhanging wall dropping to about 10 fathoms of water, is a beautiful picture of coral growth, a considerable number of species occurring side by side. A very large Crinoid lives in enormous numbers amongst these coral growths, and in many cases half a dozen or so could be picked up in a mass. Their colour was a gorgeous mixture of green and yellow, but unfortunately it left the animal's body with the greatest ease on preservation, and coloured everything else a rather dirty brownish green!

Another animal which was extraordinarily abundant on this little stretch of lagoon flat (only on the margin) was a large and beautiful Nudibranch, almost certainly new and allied probably to *Dendronotus*. The singularity of its occurrence is accentuated by the fact that notwithstanding its abundance here, not a specimen was captured anywhere else at the Abrolhos, and on our second visit in 1915 it was just as common at this place as two years before.

Large simple Ascidians and a large species of Serpulidæ were marked features of this reef-margin. On the seaward side several species of Chitonidæ were obtained, *Cryptoplax* sp. being fairly common. Sea-Urchins (chiefly *Echinometra mathæ*) occur in large numbers, each individual in a little hollow in the reef-flat which it has excavated and into which it fits. Nudibranchs and Tectibranchs (*Aplysia* sp.) were

extremely common. We could have obtained hundreds of specimens of *Aplysia* by merely picking them up as we waded in the shallow water. Under the larger coral blocks was a rich ascidian and sponge fauna, and one or two cidarids were obtained. Alpheids and other Macrura abound.

Reference must be made also to our dredge hauls. We dredged in the lagoon, but obtained little except on certain patches where we procured several species of Ascidians (simple and compound) not met with elsewhere, and some coral blocks with Brachiopods adhering to them. Against the edge of the reef-flat (lagoon) we obtained little else but fragments of rotten coral, and, as already pointed out, further north we obtained coral mud and nothing else.

In the passage south of Wooded Island the dredge brought up great quantities of weed. We have already referred to the algæ as being common at other places. As a matter of fact, it appears strange to the writer to find so much coral growth and a rich algal flora in close proximity. Unfortunately I have not yet been able to see a coral reef in real tropical waters—the comparison with the Abrolhos would be interesting in many respects. On our last expedition to the Abrolhos we made a good collection of these algæ and they now await examination.

THE PELSART GROUP.

We have emphasized the fact that the Abrolhos Islands are extremely far south for a rich growth of reefs. It is interesting to note that it is the Pelsart Group—the most southern group of the Abrolhos Islets—which most resembles an atoll, and which has given us our best collecting. It is also the historically interesting region of the Abrolhos.

The Pelsart "Group" consists of a more or less triangular lagoon bounded on two sides by a continuous coral reef, and more or less open to the sea on the north. There are three small islets in the lagoon—Gun Island, Middle Island, and Square Island—together with some smaller islets not all properly charted. Deep water is found closer to the encircling reef than to the outer islets of any of the other Abrolhos Groups, and, on the ocean side, depths of over 100 fathoms are quite near, whilst even on the eastern side the depths are at least two or three fathoms greater than to the east of the more northerly islets.

The Western margin of the Pelsart Atoll is formed of a long reef extending for upwards of 14 miles without any breaks, and without any heaping of coral fragments above high-tide level to form islets. This reef rises about one foot so above low-water mark.

On the Eastern side of the Pelsart Lagoon there is a typical rim islet—Pelsart Island. This is the longest in the Abrolhos Group and extends for about eight miles. It is quite narrow, being in some places only a few hundred feet across. At the extreme southern end of Pelsart Island (which

runs roughly N.N.E.–S.S.W.) the reef runs S.W. for a little distance, and then curves round to continue in a north-westerly direction as the western part of the encircling reef. Thus, there is no entrance into the lagoon over the encircling reef between the northern extremity of Pelsart Island on the east, and the northern end of the Western Reef (see text-fig. 8). On the North, however, the lagoon is open to the channel between the Pelsart and Easter Groups (the Zeewyk Channel), and the encircling reef is represented by a large number of scattered reefs and islands. There is quite a collection of these at the north-eastern corner of the lagoon (the Mangrove Islands of the Chart). On our second expedition we anchored the lugger amidst these islets and used the motor dinghy for work in the lagoon. On the first expedition we sailed the lugger through the lagoon (beating all the way against the dominant southerly wind) to the southern extremity of Pelsart Island, where we anchored not far from the ruins of a wooden jetty. When still some distance away from the encircling reef one hears the continued thunder of the breaking waves, for the ocean swell comes in unhindered till it meets this coral barrier. One can often see the white breakers when several miles away owing to mirage effects. This effect was noted by Kent, whose observations at the Abrolhos Islands were confined chiefly to the Pelsart Islands, and a half-tone production of a photograph showing these breakers is given in his work 'The Naturalist in Australia' (page 132).

A steady wash of water is apparently the usual occurrence over the southern and south-western part of the encircling reef into the lagoon, and consequently a current of some strength is met with in the latter, the water running from south to north. As a result, the lagoon water to the north is more free from debris than that towards the southern part of the lagoon. This factor determines to a large extent the position of lagoon coral growths.

The lagoon is roughly 11 sea miles across where it is widest, and about 8 miles from north to south. One does not meet with the same depths that are found in the Easter or Wallaby Groups, and over a very considerable part of the area of the lagoon the depth varies round two, three or four fathoms. This applies to the whole of the southern end where the depth is only 6–8 feet, except for a channel which is indicated on the chart and runs S.S.E. towards the southern end of Pelsart Island. In this channel depths round 10 fathoms are recorded. There is a very considerable difference indeed between the floor of the lagoon in different parts. At the southern end it is flat, with a floor of level coral covered with but little sand, except in patches. Probably the current is too strong for deposition of debris except in certain places. No live coral growths were observed here. The bottom of the lagoon near Pelsart Island, and about opposite the middle of its length, is somewhat similar but with a greater deposit of sand. To the north-east of the lagoon (the part shaded on the map, text-fig. 8, between

Square Island and the northern extremity of Pelsart Island), the lagoon is broken up in the most extraordinary way by reefs. The best illustration of their character, that I can think of, is to refer the reader to the well-known "maze" constructed of hedges that one meets with in certain of our famous English gardens. Our attempts to find a way through the lagoon at this place, with the motor dinghy, were absolutely the same as those of an unfortunate stranger in a "maze." The "hedges" of the maze are represented by coral reefs rising vertically from the bottom of the lagoon and having flat tops which stand a little above low-water mark. They are circular, semi-circular, straight, and of all manner of shapes. The water between them is often of considerable depth, 13 to 16 fathoms in fact, and one careers along happily for a little distance only to find perhaps a blind end in front. This means a return and another trial along some other channel.

Rich coral growths are found in this north-eastern corner of the lagoon, and, as a matter of fact, this is the only place in the Abrolhos Group where we found fields of Madrepora so close to the surface that they were exposed at very low tide. This observation fits in with Saville Kent's "chromo" made twenty years ago, but Kent did not know that he had pictured about the only spot in the Abrolhos Group where such a growth of coral prevailed.

I am convinced that the greater part of these lagoon reefs in the north-eastern area of the Pelsart Atoll are due directly to coral growth from the bottom of the lagoon, and not to the erosion of an elevated area. Their sides rise almost vertically from the bottom, but growths extend outwards from the top, and frequently overhanging portions break off and fall to the bottom to be overgrown by fresh coral. Wherever coral growth is not taking place one finds erosion, deposition of sand, or a temporary state of equilibrium. The atoll is the result of no single factor, but of a complex interaction of vital, physical, and chemical components.

The larger islets of the lagoon were unfortunately (owing to lack of time) but cursorily examined, but some of the smaller ones on the north were visited several times and Pelsart Island itself was examined more closely. The smaller islets consist of coral rocks and debris heaped up by the waves. Some of those in the north, however, seem to have suffered an elevation of a few feet, and this also applies to Pelsart Island. The coral fragments do not remain loose but are compacted together by secondary deposition. A well near the southern end of Pelsart Island enables one to obtain a glimpse of 10–12 feet of rock, all of which is coral conglomerate. Much of Pelsart Island is composed of loose fragments still, and in some places there are enormous quantities of gasteropod shells which have been thrown up. The island is 6–8 feet above sea-level, and sand and guano deposits occur here and there. Guano workers have, however, visited this island, and consequently the surface deposits have been somewhat tampered with.

Mangroves rise from the lagoon flat at many points on the shore of Pelsart Island, and they also occur on some of the Northern Islets. This coral flat, however, is not to be found forming the lagoon shore of Pelsart Island along its entire length ; there are many stretches of sandy beach, the sand forming a covering over the limestone flat.

There remains for further consideration the encircling coral reef to windward of the lagoon. On approaching this barrier at low tide, and from the lagoon, one draws near to a kind of great natural weir over which the ocean water flows almost constantly. The reef is two or three hundred feet across and the surface is smooth and well worn by the water. Few blocks of loose coral are to be found on it and practically no stones to turn over, except where they lie in a hollow—a rock-pool at low tide. Besides these small pools, however, there are large cavities—great pot-holes. Near the lagoon margin in one or two places were also irregular excavations which were perfect pictures at low tide, for amidst the scattered coral growths were long needle-spined echinoids and thousands of fishes—huge Gropers (*Acherodus gouldii*) and other species which probably enjoyed the seclusion of these cavities so well supplied with food. The antennæ of the large Crayfish *Panulirus penicillatus* projected everywhere from the crannies. We have already remarked that there are no islets on the western margin of the atoll. It would appear as if the ocean swell was too powerful to allow any heaping of coral fragments to take place. Broken pieces of coral must be constantly thrown on the reef from the outer face and yet there is no collection of this on the reef itself. The lagoon is noticeably more shallow near this windward side than against Pelsart Island to leeward. Some idea of the force of the waves is apparent from the fact that half the engine-room and some other sections of a ship, the ' Windsor,' now lie littered on this reef not far from the southern extremity of Pelsart Island. They have been picked up from the bottom outside the reef and thrown on top of it.

The Fauna of the Pelsart Group.

There is little to add regarding the terrestrial fauna of the islands. As might be expected, it is poorer than that of the islands of the more northern groups. The bird fauna alone is abundant, and many species were found nesting in considerable numbers, including Mutton-birds, Sooty Terns, Noddy Terns, and Ospreys. Beyond a small lizard, which occurred also on Rat Island, no other vertebrates were observed.

The marine fauna, on the other hand, was decidedly interesting. In this connection we may mention certain dredge hauls taken in the Zeewyk Channel just north of the Pelsart Group. The bottom was sandy with lumps of worn nullipore and shells. The dredge brought up hundreds of Holothurians of two or three species, one being particularly common. Large quantities of Cidarids were common at the same place, but there were few

star-fish and these practically all Ophiuroidea. In contrast to the hauls at almost all other places, we obtained but few sponges and fewer ascidians.

Our most interesting finds were obtained by shore-collecting on the outer reef, starting from the southern extreme end of Pelsart Island and working south and west. At this spot we obtained the first specimens of any Enteropneust to be recorded from the West coast of Australia. They were found in the coarse sand which lies in a few places, sheltered in shallow hollows on the reef-flat close to the lagoon. On both expeditions we obtained them by sifting the sand through the fingers, and nowhere else but here on the Pelsart Reef were we successful in finding any. The animals were translucent and of a pale yellow colour. They varied in size, one of the larger specimens measuring 12 centimetres when somewhat contracted. After fixation very great contraction takes place and dimensions of fixed specimens are of little value. The species has been described by the author in another paper, and is regarded as a new species of the genus *Ptychodera* allied to *P. flava*. It has been called *Ptychodera pelsarti* after the famous voyager whose ship was wrecked on the group now bearing his name *.

On the same reef, in close proximity to the spot where *Ptychodera* occurs, we found a large species of Pagurid particularly common—each shell bearing three or four large anemones. The gephyrean *Bonellia* was found for the first time on the coast of West Australia. It has since turned up several times on the coast, off Fremantle, but the species has not yet been investigated.

The Pelsart Atoll seems to be a particularly happy ground for Echinodermata. Several species of Echini occur on the floor of the lagoon, each occupying its own area. A very fine species, resembling the English *Echinus esculentus* in size, occurs in immense numbers on the floor of the lagoon at the southern end of the atoll. In another region not far from this we passed over large numbers of Asterids. Very few Alcyonaria have been obtained from the Abrolhos, and so far as our collections go these were all obtained on the Pelsart Group. Some were collected on the reef near its extreme southern point, whilst others were abundant on the northern shores of the islets termed the Mangrove Islands on the chart.

Some of these islands, together with the coral reefs, form a small well-sheltered area known by the fishermen as Whale's Bay. It is entered by a narrow channel from the north, and, as it is quite close to the open sea and in a very suitable position for departures to Geraldton, it is well frequented by the fishermen, who anchor there for the night. I was informed that the spot was well known to the fishermen as a place to which whales resorted to scrape off their attached barnacles. The skipper of our lugger said that they had on more than one occasion had a whale scraping itself against the anchor

* Journ. Linn. Soc., Zool. xxxiii. (1916) pp. 85-100, pls. 10, 11.

chain. I was rather sceptical at first about these stories, but am quite certain now that whales do resort to this small enclosed area for this purpose, for we had visitors whilst I was there. As it is not easy to find the entrance, and the area is but small, any other good reason for the frequency of whales in this particular spot seems to me entirely wanting. The visitors whilst we were there were specimens of the Humpback.

A detailed report on the general faunistic characters of the Abrolhos Islands will be written up after the various collections have been investigated by specialists.

CONCLUSION.

The Coral Formations of the Abrolhos Islands.

It will be convenient if our observations on the coral reefs of the Abrolhos Archipelago are brought together in the form of a theory relating to the origin of these islands.

To this end it will be advisable in the first place to repeat in summarised form certain observations that have been made. They are as follows :—

1. The islands consist entirely of limestones for the greater part composed of recent corals cemented together by secondary deposits of carbonates. In places, as, for example, the lowest rock exposures on West Wallaby Island, the limestone consists of foraminifera, echinoid spine fragments, and nullipore fragments, cemented together by secondary carbonates into a compact rock. The corals and molluscs are all recent and shallow-water species.

No signs of any plutonic rock, or other rock older than the limestone mentioned above, are to be found.

2. The more northerly islands, *i. e.*, the large central islands of the Wallaby Group, show signs of considerable elevation, cliffs of limestone rising to heights of 30 feet. The islands of the southern groups are not nearly so high.

3. All the island groups show evidence of a more recent elevation of about 8 feet. This is marked by the terrace on the East and West Wallaby Islands, and by the uniform flat worn surface of other islands which rise to about the height of this terrace, *i. e.*, Rat Island, some parts of Wooded Island, Gun Island, Pelsart Island (part), and some of the Mangrove Islands.

4. The most southern group of the Abrolhos Islands, the Pelsart Group, takes the form of an atoll. The lagoon depths are moderate, 17 fathoms being the greatest recorded, and the depths on the outside of the encircling reef are not very great, averaging probably about 30 fathoms, but not less on the west side where the depths are considerable a few miles away. This absence of depth is due to the fact that the atoll rises from the continental shelf, which is uniformly level over a considerable area. Had this sea-bottom sloped more rapidly, there is no doubt that the outward growth of the

encircling reefs with talus formation would have resulted in greater depths on the western side of the encircling reef.

In this connection it is worthy of note that Darwin in an appendix to his famous work, 'Coral Reefs,' p. 230, refers to the Abrolhos, about which it is true he had very little information, in the following terms :—

"Houtman's Abrolhos (lat. 28° S. on west coast) have lately been surveyed by Captain Wickham (as described in Naut. Mag. 1841, p. 440) . . . . . From the extreme irregularity of these reefs with their lagoons, and from their position on a bank, the usual depth of which is only 30 fathoms, I have not ventured to class them with atolls, and hence have left them uncoloured."*

The reefs of the Pelsart Atoll cannot be said to be arranged irregularly, and the fact that the islands rise from a bank is no reason against terming any of the groups an atoll, unless we argue that every atoll must be formed according to Darwin's views.

5. I consider that the Wallaby and Easter Groups represent stages in the formation of such a type as the so-called Pelsart Group. Easter Group, for example, can be compared with an atoll having still a large island in the centre of the lagoon. The Wallaby Group is least like an atoll and consists of a group of islets, the remains of a large limestone mass, surrounded by irregularly arranged reefs. North Island is still practically only an elevated limestone topped with sand dunes and rising from a reef-flat which extends seawards. Lagoon formation is only commencing on its eastern side, and encircling reefs cannot be said to exist. It is possible that North Island will develop along the lines indicated by the other groups.

There are several interesting points of resemblance between the Wallaby, Easter, and Pelsart Groups. In the first place, the large openings into the lagoons are always found to the north. This is the only way into the Pelsart Atoll. Both the other groups can be entered from the south, but careful navigation of the channels is required. We find a long rim islet without a break, in the Pelsart Group, and we have noticed that there is evidence of confluence of the rim islets in the Easter Group to bring about a similar condition. More primitive conditions prevail in the Wallaby Group and the rim islets are not even regularly placed. It will be noticed that rim islets are developing on the eastern, the leeward, side *in each group*.

6. Judging from the presence of certain elements in the fauna of the Wallaby Islands—the Wallabies, and the Amphibia—it is extremely probable that land connection existed between the mainland of Australia and this part of the Abrolhos Group at least.

The foundation of the Abrolhos Groups is probably Tertiary limestone, but of this we have no very direct evidence. It is worthy of note, that north of

* Uncoloured on the map given by Darwin.

the Abrolhos Islands the sea is deeper at a similar distance from the coast. In other words, the Abrolhos Islands rise from a bank connected with the coast. We must start therefore from the stage when limestones formed largely of corals, foraminifera, mollusca, and calcareous algæ were elevated in this region and united to the mainland of Australia. In fact, the west coast of Australia may be said to have been brought much further west.

This elevated limestone was weathered and eroded, and it is very likely that the channels between the present groups of islands bear some relation to the presence of small rivers, the Hutt River, the Bowes River, and the Chapman River, opening on the adjacent coast. During this period the Wallabies and Amphibia inhabited the extreme western region of the coast now represented by the East and West Wallaby Islands.

This period of elevation was followed by one of depression or subsidence, and of this there is ample evidence on the present West Australian coast. Jutson* states: "In the vicinity of Perth the coast-line was formerly farther west, as indicated by the drowned valley of the Swan River." Further examples occur in the south-west and also to the north. Thus the same author states, "The North coast is the most broken in West Australia. Deep sounds and bays run far into the land, and are manifestly the drowned continuations of the adjacent rivers. This region has been deeply dissected, probably to maturity, and then submerged. It thus affords excellent illustrations of drowned valleys."

This subsidence may be considered to have separated the Abrolhos Islands from the mainland. It is also possible that a fault running approximately N. and S. occurs between the islands and the mainland, and has helped to bring about separation, for there are several faults running parallel with the coast in this region. In any case subsidence together with erosion resulted in the separation of probably four land masses from the mainland, the ancestors of the present four groups.

We have now four islands of coral limestone, and we may assume that either the altitude of the more northern ones was higher than that of the others before subsidence, or else that the subsidence was not uniform and the southern island was depressed most. This is to account for the much greater altitude of the Wallaby Isles to-day.

Around the original islands encircling reefs have developed, whilst at the same time erosion has taken place and tended to remove them, lagoons taking their place. Such erosion has produced least effect so far in the Wallaby and North Island Groups, probably owing to their greater elevation to start with. Evidence of this erosion is everywhere present. The East and West Wallaby Islands have been separated, and a series of small islets to the east of them are all remnants of the original central mass. An excellent

* Jutson. "An Outline of the Physiography of Western Australia." Bull. 61. Geol. Surv. West. Australia. Perth, 1914.

LIMESTONE CLIFF, TURTLE BAY.

LESSER NODDY NESTING ON MANGROVES.

NODDY TERNS.

Fig. 4.

Fig. 5.

ABROLHOS ISLANDS.

Fig. 6.

Fig. 7.

ABROLHOS ISLANDS.

illustration of this erosion is left on the reef-flat to the west of West Wallaby Island and is depicted (Plate 14. fig. 7). It consists of a limestone mass which overhangs on all sides, and agrees entirely in structure with the rock of the adjacent island a few hundred feet away. A few more years and it also will have gone.

Erosion has done much more in the Easter Group, where the original central mass is now represented by Rat Island. The lagoon is deep, particularly on the eastern side, and there are several islets on the encircling reef to the east, of which Wooded Island is an excellent example. These islands consist for the greater part of heaped coral fragments, loose or cemented into a conglomerate, and very frequently lagoonlets are present on them.

In the Pelsart Group the central mass is now represented by only small islets, and they are few in number. The outer reef is much more regular than in the other groups, and is practically unbroken on two sides.

So far, we have emphasized the action of the sea in producing the lagoons. We must add that in some places the reefs are progressing seawards on the outward margins by coral growth, whilst the area of the lagoons is increasing.

Small reefs occur irregularly in all the lagoons. In some places they represent portions of the original limestone mass; in others, as for example near the Easter Passage and at the N.E. end of the Pelsart lagoon, they have grown up from the floor of the lagoon.

Thus in the formation of the lagoons at the Abrolhos Islands the greatest factor has been that of erosion and solution. Coral growth has modified this action in places, and the heaping of coral blocks by waves and currents must be also taken into consideration. Subsidence has played practically no part in lagoon formation.

As to the future, the East and West Wallaby Islands and their adjoining fragments will be probably still further reduced. Rat Island in a similar manner will be further eroded, and the Easter Group become still more like a typical atoll. The depth of the Pelsart lagoon at the extreme southern end will probably decrease owing to deposition of material washed over the encircling reef.

APPENDIX.

In the concluding section immediately preceding this, a short summary of the observations on the coral formations of the Abrolhos Islands has been given. To this we may add a short summary of other data.

1. The Percy Sladen Trust Expeditions to the Abrolhos have been arranged for the purpose of obtaining information regarding the formation of the islands, the conditions permitting of coral-reef formations in this southern

latitude (the Abrolhos are probably the most southern coral islands in the world), and the fauna of this region of the southern Indian Ocean.

2. There is evidence that the temperature of the sea at the Abrolhos is usually some degrees higher than at the adjacent coast, and that as a result the temperature during the winter months rarely falls below 20° C.

3. In consequence of this hydrographical condition, the temperature of the water at the Abrolhos only very exceptionally falls below a point that is detrimental to the active growth of reef-building corals.

4. The difference in temperature between the coastal waters and those 50 miles out, is due to a tropical current from the North and North-East, which passes down the coast but is deflected away from it, leaving a strip of colder water against the land.

5. Any phenomenal preponderance of tropical species in the marine fauna of the Abrolhos region of the Indian Ocean is due to this tropical current. It remains to be seen, when the collections are worked up, to what extent the marine fauna is a mixture of Tropical and Southern types*.

6. A great blank in our knowledge of the distribution of marine organisms in the southern Indian Ocean will be filled up by the study of these collections from the Abrolhos region in conjunction with those to be obtained from an expedition to the north-western coast of Australia, which is to follow as part of this investigation.

The collections so far examined give every indication of this, as for example the record of a new Enteropneust, and many species of other groups for the first time on the West Australian coast.

EXPLANATION OF THE PLATES.

Plate 10.

[Fig. 1.] Face of Limestone cliff, Turtle Bay, East Wallaby Island.

Plate 11.

[Fig. 2.] Lesser Noddy, on nest in Mangrove Swamp.

Plate 12.

[Fig. 3.] Noddy Terns nesting on Rat Island.

Plate 13.

Fig. 4. North-eastern coast of East Wallaby Island.
Fig. 5. Limestone cliffs, Turtle Bay, East Wallaby Island.

Plate 14.

Fig. 6. Undercut Limestone, North Island.
Fig. 7. Limestone "Pinnacle" on reef-flat, West Wallaby Island.

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* The fishes, at least, appear to be chiefly Southern forms.